NATIONAL SCIENCE FOUNDATION

HEARINGS

BEFORE THE

SUBCOMMITTEE OF THE
COMMITTEE ON APPROPRIATIONS
HOUSE OF REPRESENTATIVES

EIGHTY-FIFTH CONGRESS

SECOND SESSION

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REVIEW OF THE FIRST ELEVEN MONTHS OF THE INTERNATIONAL GEOPHYSICAL YEAR

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DEPOSITED BY THE
UNITED STATES OF AMERICA

NATIONAL SCIENCE FOUNDATION

MONDAY, JUNE 2, 1958.

REVIEW OF THE FIRST 11 MONTHS OF THE INTERNATIONAL GEOPHYSICAL YEAR

WITNESSES

INTRODUCTORY REMARKS

DR. ALAN T. WATERMAN, DIRECTOR, NATIONAL SCIENCE FOUNDATION

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DR. JOSEPH KAPLAN, CHAIRMAN, UNITED STATES NATIONAL COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR; PROFESSOR OF PHYSICS, UNIVERSITY OF CALIFORNIA

LOWER ATMOSPHERE AND THE EARTH

IGY OCEANOGRAPHY PROGRAM

DR. ROGER R. REVELLE, MEMBER, USNC TECHNICAL PANEL ON OCEANOGRAPHY; CHAIRMAN, SPECIAL COMMITTEE ON OCEANOGRAPHY OF THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS; DIRECTOR, SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA

IGY GLACIOLOGY PROGRAM

WILLIAM FIELD, CHAIRMAN, USNC TECHNICAL PANEL ON GLACIOLOGY; HEAD, DEPARTMENT OF EXPLORATION AND FIELD RESEARCH, AMERICAN GEOGRAPHICAL SOCIETY

IGY METEOROLOGY PROGRAM

DR. HARRY WEXLER, MEMBER, UNITED STATES NATIONAL COMMITTEE FOR THE IGY; CHIEF SCIENTIST, ANTARCTIC PROGRAM; DIRECTOR OF METEOROLOGICAL RESEARCH, UNITED STATES WEATHER BUREAU

IGY PROGRAMS IN SEISMOLOGY, GRAVITY, AND LONGITUDES AND LATITUDES

DR. MERLE A. TUVE, MEMBER, UNITED STATES NATIONAL COMMITTEE FOR THE IGY; DIRECTOR, DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON

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ALAN H. SHAPLEY, VICE CHAIRMAN, UNITED STATES NATIONAL COMMITTEE FOR THE IGY; CHIEF, SUN-EARTH RELATIONSHIP SECTION, CENTRAL RADIO PROPAGATION LABORATORY, NATIONAL BUREAU OF STANDARDS

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DR. JOHN A. SIMPSON, MEMBER, UNITED STATES NATIONAL COMMITTEE FOR THE IGY; PROFESSOR OF PHYSICS, UNIVERSITY OF CHICAGO

IGY PROGRAMS IN AURORA AND AIRGLOW

NORMAN J. OLIVER, VICE CHAIRMAN, USNC TECHNICAL PANEL ON AURORA AND AIRGLOW; CHIEF, IONOSPHERIC PHYSICS SECTION, GEOPHYSICS RESEARCH DIRECTORATE, AIR FORCE CAMBRIDGE RESEARCH CENTER

IGY ROCKETRY PROGRAM

DR. HOMER E. NEWELL, JR., VICE CHAIRMAN, USNC TECHNICAL PANEL ON ROCKETRY; SUPERINTENDENT, ATMOSPHERE AND ASTROPHYSICS DIVISION, NAVAL RESEARCH LABORATORY

IGY SATELLITE PROGRAM

DR. RICHARD W. PORTER, CHAIRMAN, USNC TECHNICAL PANEL ON THE EARTH SATELLITE PROGRAM; CONSULTANT, COMMUNICATION AND CONTROL, GENERAL ELECTRIC CO.

OTHER WITNESSES

HUGH ODISHAW, EXECUTIVE DIRECTOR, USNC–IGY
J. WALLACE JOYCE, HEAD, OFFICE FOR THE INTERNATIONAL GEOPHYSICAL YEAR, NSF
J. E. LUTON, ASSISTANT DIRECTOR FOR ADMINISTRATION, NSF
F. C. SHEPPARD, COMPTROLLER, NSF

Mr. THOMAS. The Committee will please come to order.

Again we have assembled to review the International Geophysical Year program and receive some interesting lectures from our distinguished friends. They will bring us up to date on the accomplishments of the International Geophysical Year so far and what the prospects are in the way of future developments.

Gentlemen, the Committee is certainly delighted and honored to have such a distinguished group with us. When we look at this group we know that those Russians cannot get too far ahead, and of course, the results of the ingenuity and the genius of this crowd is going to be the future industrial development of the country.

As far as the Committee is concerned—and I am sure I speak the sentiments of the committee—this is the cream of the crop.

I am going to read the names of the distinguished witnesses into the record together with their full title.

We are again delighted to have with us Dr. Alan T. Waterman, Director, National Science Foundation, and our young friend of many

years standing, the Chairman, Dr. Joseph Kaplan, Chairman, United States National Committee for the International Geophysical Year and professor of physics at the University of California. Welcome aboard, Doctor.

Where is Dr. Revelle?

Dr. WATERMAN. He has not arrived yet.

Mr. THOMAS. Next is Dr. William Field, chairman, USNC Technical Panel on Glaciology, and head of the department of exploration and field research of the American Geographical Society. Dr. Field, we are glad to have you.

Then we have Dr. Harry Wexler, who is a member of the United States National Committee for the IGY and chief scientist of the Antarctic program as well as Director of Meteorological Research of the United States Weather Bureau.

Do you mean, Dr. Wexler, that our friend Dr. Gould has not frozen you out yet?

Dr. WEXLER. No, sir.

Mr. THOMAS. Now we have Dr. Laurence M. Gould, who is a member of the United States National Committee for the IGY and director, USNC Antarctic program, as well as chairman of the Committee on Polar Research of the National Academy of Sciences and president of Carleton College.

Dr. WATERMAN. Dr. Gould cannot be here, Mr. Chairman.

Mr. THOMAS. I understand he was planning to come. We are sorry he could not make it.

Next we have Dr. Merle A. Tuve, who is a member of the United States National Committee for the IGY and director of the department of terrestrial magnetism of the Carnegie Institution of Washton. Dr. Tuve, it is good to see you again.

Dr. TUVE. Thank you, Mr. Chairman.

Mr. THOMAS. Now we have Mr. Alan H. Shaply, who is Vice Chairman of the United States National Committee for the IGY and Chief of the Sun-Earth Relationship Section, Central Radio Propagation Laboratory of the National Bureau of Standards.

Then we have Mr. Norman J. Oliver, who is Vice Chairman of the USNC Technical Panel of Aurora and Airglow and Chief, Ionospheric Physics Section, Geophysics Research Directorate, Air Force Cambridge Research Center.

We are pleased to have with us Dr. John A. Simpson, who is a member of the United States National Committee for IGY and professor of physics at the University of Chicago.

Next is Dr. Homer E. Newell, Jr., Vice Chairman, USNC Technical Panel on Rocketry, and Superintendent, Atmosphere and Astrophysics Division, Naval Research Laboratory.

Next is Dr. Richard W. Porter, Chairman, USNC Technical Panel on the Earth Satellite Program and consultant, communication and control, General Electric Co.

Then we have our old friends Mr. Odishaw, Executive Director, USNC-IGY; Mr. J. Wallace Joyce, Head, Office for the International Geophysical Year, NSF; Mr. J. E. Luton, Assistant Director for Administration, NSF; and Mr. F. C. Sheppard, Comptroller, NSF.

Dr. Waterman, we should like for you to handle this program and we will continue in any manner that you see fit. Do you have any suggestions to make?

Introductory Remarks

Dr. Waterman. Thank you, Mr. Chairman. We are very pleased to have this opportunity to come before the committee to talk about the progress of the IGY. It has been several years, as the Committee will recall, since the National Science Foundation made its request for funds for an International Geophysical Year.

Mr. Thomas. It was July 1954, and the law was signed August 26, I believe.

Dr. Waterman. That is right. It was for fiscal 1955 that we had our first request and I believe that many of these gentlemen at that time went into detail on the plans of the program which was presented. The planning has been in the hands of the United States National Committee of the National Academy of Sciences.

I should like to take this opportunity to state our great appreciation of the support of yourself and this Committee in this program because it has worked out extremely well and the planning by the National Committee in cooperation with other nations has been of a very high order. One need only say that the program by the United States as planned by the Committee and carried out, has been right along the lines of the original plans. The United States has gone forward with its program, and in detail, and they have worked it out in accordance with the original plans that you have heard.

Mr. Thomas. It is remarkable, is it not?

Dr. Waterman. It is. The cooperation of other nations has been remarkable as well.

Mr. Thomas. Off the record.

(Discussion off the record.)

Dr. Waterman. It is, of course, as you gentlemen know, a program of basic research and as such one can never be quite certain what the findings will be. But as you will hear from the gentleman today, the findings have been very significant in certain fields and in some cases unexpected. As for its practical results, we will tell you something on that and what the consequences might be.

The two major fields where one can probably expect the most immediate results may be the fields of meteorology and communication. It is certain that what is found in the IGY will have a profound effect upon our fundamental theories and that always, in the history of research, constitutes a very great advance, but certainly the practical consequences are not entirely to be confined solely to those fields. The field of oceanography, for example, would be another one and, of course, the whole Antarctic Continent and what is found there is completely new.

Mr. Thomas. Off the record.

(Discussion off the record.)

Dr. Waterman. These gentlemen who are present today with us are those who have been in charge of the major segments of the program and will speak to these various fields in detail. They, of course, are experts in their field, Mr. Chairman. Many of them are already known to you.

At this point with your permission, Mr. Chairman, I should like to turn the program over to Dr. Kaplan who will introduce the speakers in order as he would like to have them and who will present the overall picture to you.

Mr. THOMAS. Doctor, we are certainly delighted to have you with us again. You are an ex officio member of this committee anyway.

Dr. KAPLAN. Thank you very much. I might say that I have enjoyed being an ex officio member of this committee.

Mr. THOMAS. You are wonderful.

Dr. KAPLAN. Needless to say, I am happy to come before the committee again and with your permission shall introduce each of the speakers.

Mr. THOMAS. Surely.

SUMMARY OF IGY PROGRAM

Dr. KAPLAN. I should like to offer for the record at this time, Mr. Chairman, a prepared statement.

Mr. THOMAS. Without objection it will be inserted in the record at this point.

(The statement referred to follows:)

A SUMMARY OF THE UNITED STATES IGY EFFORT

I am most happy to come again before this committee, and I appreciate the opportunity which has been given me to review for you the progress up to the present time of the United States program for the International Geophysical Year. Since we appeared before you in May last year to review our program, the IGY has made great strides and is now more than halfway through its 18-month period.

As you are already well aware, most encouraging scientific observations have been made during this period, and I have brought along with me a group of the scientists intimately concerned with the different aspects of the program to report to you on progress in the various fields. We are all more certain than ever that this International Geophysical Year will be one of the greatest scientific efforts ever encompassed on a worldwide scale.

From the international standpoint, there has been gratifying cooperation among all participating countries. One additional regional international meeting has been held since we described the program to you a year ago. Last fall, an international meeting on rockets and satellites was held here in Washington, D. C. The meeting covered a week of activities from September 30 through October 5, and papers were presented on planned rocket and satellite experiments. A fifth meeting of the CSAGI is scheduled to be held in Moscow next August to report on the progress of the program to date and to discuss plans for the termination of the IGY.

INTERNATIONAL PARTICIPATION

One of the most reassuring developments of the IGY has been the growth of international participation. At the inception of the program it was not known how many countries would join the collective effort nor how many observing stations would be set up and manned. The growth of the IGY has exceeded our fondest hopes and, at present, 66 nations and more than 10,000 scientists are actively participating in this scientific venture. The expanse and the present scope of this program can best be portrayed by the following table:

Period	Number of participating countries	Number of observing stations
July 1954, 83d Cong., 2d sess.	26	0
February 1955, 84th Cong., 1st sess.	36	426
March 1956, 84th Cong., 2d sess.	40	1,572
July 1, 1957 (opening of IGY)	66	[1] 2,500

[1] More than 2,500.

The countries participating are:

Argentina
Australia
Austria
Belgium
Bolivia
Brazil
Bulgaria
Burma
Canada
Ceylon
Chile
China: Taipei
Colombia
Cuba
Czechoslovakia
Denmark
Dominican Republic
East Africa
Ecuador
Egypt
Ethiopia
Finland
France
German Democratic Republic
German Federal Republic
Ghana
Greece
Guatemala
Hungary
Iceland
India
Indonesia
Iran
Ireland
Israel
Italy
Japan
Korea, Democratic Republic of
Malaya
Mexico
Mongolian Peoples Republic
Morocco
Netherlands
New Zealand
Norway
Pakistan
Panama
Peru
Philippines
Poland
Portugal
Rhodesia, Southern
Rumania
Spain
Sweden
Switzerland
Tunisia
Union of South Africa
Union of Soviet Socialist Republics
United Kingdom
United States
Uruguay
Venezuela
Vietnam Democratic Republic
Vietnam (Republic)
Yugoslavia

The cooperative effort extends across all fields. For instance, in solar activity, a worldwide solar patrol keeps watch on the sun all over the world throughout the 24 hours of each day. A total of 126 solar observation stations are being operated by 33 countries. In the satellite tracking program, a chain of radio tracking stations has been established north and south through the Western Hemisphere—in the United States, Cuba, British West Indies, Ecuador, Peru, and Chile; and precise optical tracking stations have been set up on an east-west band, in North America, South America, Spain, South Africa, Iran, India, Australia, Japan, and Hawaii. In oceanography, United States scientists in close cooperation with scientists and agencies of the countries concerned have set up tide gages in Bermuda, Iceland, the Azores, the Carolines, the Marshalls, French islands in the Southeast Pacific, and Pitcairn Island; and in meterology, all countries have pooled their national meteorological programs to provide worldwide coverage. One of the very unique programs exemplifying international cooperation is the world warning system set up in communications. The IGY World Warning Agency (AGIWARN) operated by the National Bureau of Standards is the central part of this system and has its headquarters at Fort Belvoir, Va., with associate and regional centers in the Netherlands, France, Germany, U. S. S. R., Japan, Australia, Antarctica, and Alaska. Daily status reports are sent to AGIWARN, and warnings are issued placing all sites throughout the world on notice that unusual solar or geomagnetic activity may be in the offing.

OBSERVATIONAL PROGRAM

The observational program got off to an explosive start. On June 28, 1957, a major flare occurred on the sun which was first detected at the Krasnaya Pakhra Observatory in the Soviet Union. Immediately an alert was issued and a special world interval was declared on June 29. Alerts are declared when there is a possibility of solar disturbances, and special world intervals are promulgated calling for an increased number of measurements of solar terrestrial phenomena when the probability is high that terrestrial disturbances will also occur. As of May 26, 25 alerts and 11 special world intervals have been declared.

Many interesting phenomena have been observed to date, which have influenced existing scientific theories. For instance, on July 4, 1957, radio signals were received from a rocket fired up through the ionosphere during a radio communications blackout which demonstrated the presence of an additional layer of ionization extending for about 12 miles lower than ever before believed. Even more remarkable, the rocket data showed that the normal ion distribution throughout the ionosphere seemed to remain undisturbed during the blackout. Previously it had been thought that radio blackouts were caused by an absorption of signals in the lower atmosphere due to increased ionization of the E region, the lowest normally occurring layer. In another rocket experiment it was ascertained that the additional electron layer was caused by solar X-ray emission associated with the occurrence of solar flares.

In another field the existence of a so-called electroject, the equatorial electric current, is being explored. Initial data from Koror reveal the existence of this equatorial stream and define to some extent its limited horizontal band. Rocket-borne instruments have disclosed bands of a similar intense current at a height of 56 miles above the Arctic. A comprehensive auroral observation program is underway in 49 countries, and already extensive auroral displays as far south as Habana, Cuba, have been seen. English scientists at the University of Manchester have reported that similar radar observations indicate that auroras occur simultaneously in the Northern and Southern Hemispheres.

In the observation of whistlers, early experiments have demonstrated that the ion density occurring at altitudes up to twice the earth's radius must be much greater than formerly anticipated. This may confirm the theory that the earth's atmosphere extends far beyond the level where it had been previously thought to end.

An investigation in cosmic rays intensity has shown that the cosmic ray equator deviates systematically from the geomagnetic equator. This suggests that there may well be important magnetic fields, probably of extraterrestrial origin, which alter the trajectories of the incoming primary cosmic ray particles. Perhaps one of the most interesting discoveries made in the course of IGY cosmic ray experiments was that of relatively soft radiation in the high atmosphere. From these experiments it appears that incoming auroral particles create X-rays, and that there is good correlation between the presence of such radiation and solar magnetic and auroral activity.

In the field of the earth's heat and water regimen, the disciplines of meteorology, glaciology and oceanography are concerned. Almost all of the energy that the earth receives comes from the sun. This energy evaporates water, heats the ground, which in turn heats the air above it, and in general supplies the energy to drive the winds of the atmosphere. Already in this program it has been found that the South Pole, almost 10,000 feet above sea level has 9,000 feet of ice beneath it, and Byrd Station, which sits on 10,000 feet of ice, is only 5,000 feet above sea level. The Antarctic Continent may have frozen fiords or vast frozen inland lakes contrary to previous thinking that this was a solid land mass. An undersea mountain range has been discovered in the Arctic Ocean, and ice cores from both the north and the south are establishing dates of ice accumulation in the study of the climate and precipitation over the past many hundreds of years. Streams of deep water have been discovered by research vessels in some instances flowing in opposite directions to established currents as we have known them. These three disciplines are explaining the relationship of the cold and warmth of the water, ice, and the vapor around the earth.

In the earth's crust and interior, programs of unprecedented scope are being pursued. A surface gravimeter has been developed which is enabling us to obtain gravity measurements at sea simply and quickly from surface vessels with a precision of one part per million, similar to that attainable on land. Special long-period seismographs sensitive to surface waves of periods of about 400 seconds generated only by the very longest earthquakes have been set up at observatories ranging from Hawaii to Fiji, and from Bermuda to the Antarctic, and are giving us data on the interior of the earth. The existence of certain intermediate waves previously known only in the earth's crust have been identified in the mantle of the earth or the layer next beneath the crust. Study of their propagation is expected to provide new information on the distribution of materials inside the earth. Scientists of 29 countries at 45 IGY stations around the world are determining more precisely the latitudes and longitudes. Newly developed moon position cameras, used in conjunction with Danjon impersonal astrolabes, will permit more precise locating of the earth's land mass than has been possible before.

DATA INTERCHANGE

The same cooperation that has marked the planning and observation aspects of IGY characterizes the interchange of data. This, indeed, is the primary goal of IGY. It is gratifying to report to you that the data centers are in operation and that the data are flowing. Annex A presents a rather detailed summary of the status of this activity of the IGY.

A LOOK AHEAD

I believe that the few remarks I have made, the report on data interchange, and the remarks yet to be made by my colleagues gathered here today suggest that the IGY is proceeding satisfactorily. Indeed, in my opinion, its success is not only assured but has already and will continue to exceed any of our expectations 2, 3, and 4 years ago as we met with you and as we planned this great, unprecedented human endeavor.

It is our responsibility, aside from what we have done in planning, conducting, and directing IGY, also to pause from time to time in order to appraise its meaning and its implications, not only to science but to the nation. I should like to close with a few observations in this area.

First, the IGY will lead to new opportunities in some of its fields. These are polar research, oceanography, and rockets and satellites. In the first two of these areas there are international bodies studying and planning; in the last, there probably will be a special committee set up by the International Council of Scientific Unions this fall. You are familiar with one of these fields—the one where activity is already underway: the Antarctic. You have considered this program, authorized its conduct, and provided funds for 1959. I can only say that this is a most important endeavor. Moreover, the Congress is currently hard at work on the future of space research; and this is a most exciting and challenging area for man's exploration and study.

Second, I should like to call your attention to the research, analytical and theoretical, that must be done with the precious and monumental body of IGY data—much already in and more flowing every day. Research with these data has two aspects:

1. *Normal research.*—For the next several decades hundreds and thousands of scientists will be picking up topics, using various portions of the data, in a broad variety of studies. These studies will come about in a normal way. They will be undertaken in the usual scientific way. Their support falls into the regular pattern, as far as we in the United States are concerned, of such activities. Much of the work will be in universities and will be supported by them. Some will result in project proposals directed to public and private grant-giving agencies. I expect that quite a few proposals will come to the National Science Foundation in the coming decade and also to various research offices of the Department of Defense. I foresee no major problem in this.

2. *Special research.*—If, however, we are fully and promptly to capitalize upon the IGY, a special and major effort is called for. This effort I would call a special coordinated IGY research program, characterized as follows: First, it is short range—some 2 years. Second, it is interdisciplinary in nature—that is, as against the normal research of individual scientists aimed at limited topics in a given field, it is a major, directed attack upon several interrelated fields at once. Third, it is called for by virtue of the astonishing breakthroughs already made, like the radiation zone discovered by Van Allen in satellite experiments. In this sense, it is critically important because I believe major advances can come soon and they will come; the question is only this: Will American scientists make these major discoveries? Such work will also set the pattern of research for years to come, both experimental and theoretical. In short, we have run into a unique opportunity, but this calls for prompt action. Our responsibility to you is to mention it, to bring it to your attention for your deliberations and considerations.

ANNEX A. REPORT ON DATA INTERCHANGE AND IGY WORLD DATA CENTERS

By Hugh Odishaw, Director, IGY World Data Center A

In accordance with the recommendations of the 1956 conference of CSAGI in Brussels, three world data centers were established to maintain collections of IGY data. It was decided that three data centers would insure against the loss or destruction of the data and would serve the geographical convenience of scientists of all nations.

Two IGY national committees, those of the United States of America and the U. S. S. R., each offered to establish and maintain collections of all the data. These centers were named A and B respectively. A third center, C, was made up of a number of centers each maintaining only a partial collection of data. Center C is made up of subcenters in eight nations of Western Europe, and centers in Japan and Australia.

The functions and responsibilities of the data centers as set forth by the IGY world data center meeting in Brussels in April 1957, are as follows:

(i) All world data centers will accept IGY data on all types of observations in the disciplines appropriate to the center in the form established in the CSAGI manuals.

(ii) Each center shall make every endeavor to collect a complete set of data within the field or discipline for which it is responsible.

(iii) Each center is responsible for the safekeeping of the incoming data and the correct copying and reproduction of the data, maintaining adequate standards of clarity and durability.

(iv) Each center will provide, within 2 months of receipt and on a free exchange basis, copies of all incoming data to the other centers (for the discipline) which have not received them. It is the basic recommendation that all IGY stations send copies of data to all centers or multiple copies to one center for forwarding in order to lessen the burden of reproducing data at the data centers.

(v) Each center will make a catalog of the incoming IGY data in a manner to be approved by the CSAGI secretariat. This catalog will distinguish between the data received from the IGY national committees and institutions and the data forwarded from other world data centers.

(vi) The above-mentioned catalog shall be issued at the end of each 6 months of the period of the IGY.

(vii) All world data centers shall satisfy within 3 months the demands of scientific bodies or investigators in any country for copies of material, reproduced in accordance with the rules of CSAGI. The fee charged for such material should not exceed the cost of copying and postage.

(viii) Scientific workers shall have access to the material available in each center by arrangement with the authority responsible for the center.

(ix) Data transmitted to a world data center shall be accompanied by a transmittal note devised by CSAGI which shall include the essential description of the data and shall indicate to the recipient data center to which of the other data centers copies of the data have been sent.

WORLD DATA CENTER A

World data center A was established in 11 institutions in 8 cities of the United States and Alaska. The United States national committee believes that the interests of science are served best by establishing subcenters for the various disciplines in institutions which have a history of scientific interest and competence in the appropriate geophysical field, and which have facilities to maintain the data center after the termination of IGY. The National Academy of Sciences is responsible for the direction of world data center A.

The subcenters of world data center A and their directors are given below:

(i) *Airglow and ionospheric physics.*—Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colo. Director: Mr. W. B. Chadwick, Chief of Regular Propagation Services Section of Radio Propagation Physics Division of the National Bureau of Standards.

(ii) *Aurora (instrumental observations).*—Geophysical Institute, University of Alaska, College, Alaska. Director: Dr. C. T. Elvey, head of the department of geophysics and director of the Geophysical Institute of the University of Alaska.

(iii) *Aurora (visual observations).*—Rockefeller Hall, Cornell University, Ithaca, N. Y. Director: Dr. C. W. Gartlein, technical advisor for physics and director of the Cornell Study of Aurora.

(iv) *Cosmic rays.*—School of physics, University of Minnesota, Minneapolis, Minn. Director: Dr. Paul J. Kellogg, research associate in the school of physics, University of Minnesota.

(v) *Geomagnetism, gravity, and seismology.*—United States Coast and Geodetic Survey, Geophysics Division, Washington, D. C. Director: Mr. J. H. Nelson, Chief, Geomagnetism Branch, United States Coast and Geodetic Survey.

(vi) *Glaciology.*—American Geographical Society, Broadway at 156th Street, New York, N. Y. Director: Mr. William O. Field, head of the department of exploration and field research, American Geographical Society.

(vii) *Longitude and latitude.*—United States Naval Observatory, Washington, D. C. Director: Dr. William Markowitz, Director of Time Service, United States Naval Observatory.

(viii) *Meteorology and nuclear radiation.*—National Weather Records Center, United States Weather Bureau, Asheville, N. C. Director: Dr. Helmut E. Landsberg, Chief, Climatological Services, United States Weather Bureau.

(ix) *Oceanography.*—Department of oceanography and meteorology, Agricultural and Mechanical College of Texas, College Station, Tex. Director: Dr. Dale F. Leipper, head, department of oceanography and meteorology, Agricultural and Mechanical College of Texas.

(x) *Rockets and satellites.*—National Academy of Sciences, Washington, D. C. Director: Mr. John Hanessian, Jr., program officer, United States National Committee for the International Geophysical Year.

(xi) *Solar activity.*—High altitude observatory, Boulder, Colo. Director: Dr. Walter Orr Roberts, director, high altitude observatory of the University of Colorado.

WORLD DATA CENTER B

World data center B was established by the U. S. S. R. Committee for the International Geophysical Year. Data center B is made up of 4 subcenters, 3 of which are located in Moscow. The fourth center is a partial center for solar activity. (Solar activity is divided into 10 subdivisions: 1 of these, the flare and plage indexes based on photometric measurements, is assigned to the data center in the Crimea.)

World data center B is divided according to discipline as follows:

(i) B–1: Institute of Aeroclimatology, Moscow: Glaciology, gravity, longitude and latitude, meteorology, nuclear radiation, oceanography, seismology.

(ii) B–2: Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation, Moscow: Aurora, airglow, cosmic rays, geomagnetism, ionosphere, solar activity.

(iii) U. S. S. R. Academy of Sciences, Moscow: Rockets and satellites.

(iv) The Crimea Observatory, Simeis, Crimea: Solar activity.

WORLD DATA CENTER C

World data center C was established in eight nations of Western Europe and in Australia and Japan. For several disciplines, two subcenters of world data center C exist, and are designated centers C–1 and C–2.

In addition to the world data center C, there are several organizations which have collected and published processed data for many years. It is the intent of CSAGI that the flow of data to these organizations, known as permanent services, should not be interrupted. In seismology, the permanent service is also data center C, and falls under the rules laid down by CSAGI. In several other disciplines, permanent services have agreed to a free exchange of data with the IGY world data centers. These permanent services are indicated in the following list of the subcenters of world data center C:

(i) *Airglow.*—C–1: Institut d'Astrophysique, Paris, France. C–2: Tokyo Astronomical Observatory, Mitaka, Tokyo, Japan.

(ii) *Aurora (instrumental).*—Department of electronics, Royal Institute of Technology, Stockholm, Sweden.

(iii) *Aurora (visual).*—Balfour Stewart Auroral Laboratory, Edinburgh, Scotland.

(iv) *Cosmic rays.*—C–1: Department of electronics, Royal Institute of Technology, Stockholm, Sweden. C–2: Cosmic rays laboratory, Scientific Research Institute, Itabashi, Tokyo, Japan.

(v) *Geomagnetism.*—C–1: Meteorological Institute, Charlottenlund, Denmark. C–2: Geophysical Institute, Kyoto University, Kyoto, Japan. Permanent services: Meteorologish Institut, De Bilt, Holland; Geophysikalisches Institut, Göttingen, German Federal Republic; Observatorio del Ebro, Tortosa, Spain.

(vi) *Glaciology.*—The British Glaciological Society, Scott Polar Research Institute, Cambridge, England.

(vii) *Gravimetry.*—Observatoire Royal de Belgique, Uccle, Belgium. Permanent service: Bureau Gravimetrique International, Paris, France.

(viii) *Ionospheric physics.*—C–1: Radio Research Station, Ditton Park, Slough, Buckinghamshire, England. C–2: Radio Research Laboratories, Ministry of Postal Services, Kokubunji P. O., Tokyo, Japan.

(ix) *Longitude and latitude.*—Permanent services: Bureau International de l'Heure Observatoire de Paris, Paris, France. International Latitude Service, Turin Astronomical Observatory, Turin, Italy.

(x) *Meteorology.*—World Meteorological Organization, Geneva, Switzerland.

(xi) *Nuclear radiation.*—C–1: International Institute of Meteorology, Stockholm, Sweden. C–2: Observation Division, Japan Meteorological Agency, Tokyo, Japan.

(xii) *Seismology.*—International Central Seismological Bureau, Strasbourg, France.

(xiii) *Solar activity.*—The Observatory Eidgenössische Sternwarte, Zurich, Switzerland; The Astrophysical Observatory, Arcetri-Firenze, Italy; Solar Physics Observatory, Cambridge, England; Observatoire de Meudon, Meudon, France; Observatoire du Pic du Midi, Bagneres de Bigorre, Hautes Pyrenees, France; Fraunhofer Institut, Freiburg, Baden, German Federal Republic; Radiophysics Laboratory, University Grounds, Sydney, Australia.

DATA INTERCHANGE AGREEMENTS

The general responsibilities of the world data centers were outlined earlier in this testimony. The form in which data are to be submitted has been determined by CSAGI for each discipline. All world data centers have agreed to copy all data as required to insure that each center shall receive a complete set of IGY data. Time schedules for submission of data to the data centers were arranged by CSAGI. These vary widely from discipline to discipline, hence the CSAGI agreement for each is discussed separately below:

Airglow.—There are 4 major programs organized by the 4 data centers, hence stations participating in each program contribute data to 1 data center only. Each center obtains data from its contributing stations within 3 months of the end of a month's observing period, assembles a tabular statement of the observations made and the equipment used, and exchanges these statements with the other world data centers.

Aurora (instrumental).—Each all-sky camera station, or its national center, will prepare a record of the times of operation and the presence or absence of aurora. These records will be sent at three monthly intervals in triplicate to the parent world data center for distribution to the other centers. Each center will compile such records from its stations into a single calendar at six monthly intervals.

Each station will send original film to the parent data center for copying. This center will make 3 copies, 1 for itself, 1 each for the other 2 data centers. Data will be transmitted from stations having regular postal communications on a monthly basis within 3 months.

Aurora (visual).—Visual reports of auroras will be sent by the individual observers to their national reporter at such intervals as he indicates, or, if he so advises, to a designated regional reporter. The records thus collected will be summarized in the form of charts showing the geographical distribution of the aurora over the region to which the collection refers. The charts will be microfilmed and copies will be sent to one world data center which will supply copies to the other centers. The locations of regional reporters or national centers which prepare charts are listed below according to the parent world data center:

World data center A: Buenos Aires, Argentina; Ithaca, N. Y.; Melbourne, Australia; Ottawa, Canada; Wellington, New Zealand.

World data center B: Moscow, U. S. S. R.

World data center C: Edinburgh, Scotland; Tokyo, Japan.

Cosmic rays.—Data will be prepared as numerical tabulations on monthly sheets. As a rule, stations will be able to make copies of these forms in order to provide 1 for each of the 4 world data centers. Data are to be transmitted to the data centers not later than 3 months after the end of the monthly observing period.

Geomagnetism.—Magnetograms and tellurigrams will be sent on a 6-monthly basis, with a lag of no more than 4 months after the end of the observing period. Those stations which can send data more frequently are urged to do so. C and K indices will be sent to the permanent service at De Bilt not later than 1 month after the end of the observing period. K indices and solar flare effects from selected stations will be sent to the permanent service at Göttingen within 2 weeks of the end of the observing period. Q indices will be forwarded to Göttingen within a month of receipt at the responsible national institution. One copy of these indices will be sent to one or more of the world data centers.

Glaciology.—Data in glaciology are expected to be submitted to the centers in three forms: (i) progress reports; (ii) basic data; (iii) published reports.

The progress reports should be drawn up under the following headings: (i) glacier regimen; (ii) stratigraphy of snow and ice; (iii) heat exchange studies; (iv) snow and ice physics, seismology, and gravity; (v) glacier census; (vi) other glaciological observations. These reports are to be forwarded within 3 months of the end of a field season. Basic data should follow within 6 months. Copies of published reports should be forwarded as soon as they become available, which should be before December 1959, except for the Arctic, Antarctic, and other remote regions from which final reports are expected by December 1960.

Gravimetry.—Pendulum and gravimeter data will be sent to the permanent service at Paris as soon as possible. This permanent service will coordinate results to insure their homogeneity and their relation to the world network, and will supply copies to the world data centers.

Data from earth tide studies will be forwarded within 3 months of the end of a monthly observing period.

Ionospheric physics.—Data in ionospheric physics fall under nine categories: (i) vertical incidence soundings; (ii) absorption measurements; (iii) drift measurements; (iv) atmospheric noise; (v) whistlers; (vi) backscatter; (vii) forward scatter; (viii) radar meteor observations; (ix) miscellaneous measurements. Stations or responsible organizations should forward tabulated and graphical data and the specified ionograms for a particular month to the appropriate world data center within a period of 3 months from the end of the month concerned. In the case of isolated expeditions, the data should be dispatched within 3 months of the return of the expedition. In exchange for ionospheric data received from organizations or stations, the world data centers should send free of charge, on the request of national organizations, an equivalent quantity of data.

Longitude and latitude.—Data from the Astrolabe or the PZT observations are sent to the permanent services at Paris and Turin. Data from the moon-position cameras are sent to the United States Naval Observatory. The photographic plates from the 20 moon-position cameras are sent first to 1 of 4 measuring institutions, which are the observatories at the Cape of Good Hope, Paris, Herstmonceux, and Washington. The measurements made by these observatories are then sent to the Naval Observatory. The schedules for dispatch of these data are arranged by the centers at Paris and Washington.

Meteorology.—Data in meteorology fall into two categories: (i) synoptic and dynamic meteorology (surface and upper air); (ii) radiation, ozone and atmospherics measurements. Data will be in tabular form in all projects. Standard forms have been prepared by the World Meteorological Organization at Geneva. All participating national committees are asked to send copies of meteorological data to all three data centers, or to data center C and to center A or B. Data in synoptic meteorology will be dispatched twice a month; data in radiation, ozone, and atmospherics should be forwarded on a monthly basis with a lag of not more than 6 months.

Nuclear radiation.—Measurements of fission products in the air and in the ocean and measurements of natural radioactivity in the air should be transmitted on a monthly basis within 3 months of the end of the observing period. Data from isolated stations and ships should be sent at the first opportunity and, in the case of expeditions, not later than 6 months after their return.

Oceanography.—There are two kinds of recordings in oceanography: (i) stations ashore; (ii) stations afloat. Shore stations record sea level and long period waves. Measurements from ships include: (i) chemistry and physics of the water; (ii) state of the sea and swell; (iii) currents; (iv) depth measurements; (v) bottom sediments; (vi) meteorology; (vi) biology.

Cruise data are to be forwarded as expeditiously as possible, not later than 6 months after completion of the cruise. Data are to be sent to each data center if feasible or, alternatively, 2 copies sent to 1 center, 1 to be forwarded to the other center.

Rockets and satellites.—After each rocket firing, the responsible institution will, within 4 weeks if possible, forward a flight information summary, which gives the time and location of launching, and the geophysical experiments being performed.

As soon as possible after a satellite launching, but in no case more than 24 hours later, information needed by cooperating observers is to be promulgated by the IGY authority effecting the launching. A message is to be sent on the World Days Interchange Network (AGIWARN) containing the following information: (i) launching time and place; (ii) orbital information; (iii) ra-

dio frequencies transmitted from the satellite; (iv) description of the objects in orbit.

The IGY authority for the launching of satellites will be primarily responsible for computing and communicating predictions to cooperating observers at appropriate intervals during the life of the satellite. Observations by cooperating observers should be transmitted telegraphically within 1 day to the primary prediction authority.

Preliminary reports of satellite experiments will be published by the launching authority several weeks after a launching. Within 12 months after the end of each experiment, the full scientific reports of rocket and satellite experiments will be published in available literature. Copies will be sent to the world data centers.

Seismology.—There are three kinds of seismic observations in IGY: (i) standard seismic and microseismic measurements; (ii) special systematic investigations, e. g. strain accumulation; (iii) crustal studies. Stations will prepare a regular monthly bulletin containing as complete an analysis as is possible from the reduction of the data obtained from seismograms. The measurements of microseismic disturbances should be similarly assembled in regular monthly bulletins. Studies of the earth's crust and other special studies should appear in the national annual reports to be published beginning in 1958.

Original seismograms, both for regular and for special studies, will not be sent to the world data centers except on special request for making copies. Bulletins and annual reports should be sent to each world data center within two weeks after they become available.

The different central seismological services operating stations in the Arctic and Antarctic during IGY are requested to exchange bulletins every 10 days if possible.

Solar Activity.—The discipline of solar activity is subdivided into ten types of solar phenomena: (i) Wolf sunspot numbers; (ii) special sunspot numbers; (iii) radio emission; (iv) calcium plages; (v) solar magnetic fields; (vi) solar flares; (vii) flare and plage indices; (viii) active prominence regions; (ix) chromospheric structures; (x) corona isophotes.

Center A: Central Radio Propagation Laboratory is the data center for the first 3 of these subdivisions; the High Altitude Observatory is the data center for the remaining 7.

Center B: The Crimean Observatory is the data center for the flare and plage indices. World data center B–2 in Moscow is the data center for the remaining nine subdivisions.

Center C: According to the number of the subdivision given above, the data center C for solar activity is as follows: (i and ii) Zurich; (iii) Sydney; (iv) Arcetri; (v) Cambridge; (vi, vii, viii) Meudon; (ix) Freiburg; (x) Pic du Midi.

The agreements for the submission of data differ somewhat among the subdivisions. The significant points are the following: Communications should be sent by telegram via the regional warning centers as soon as possible after important solar flares are over (within 1 hour). Summaries of intensities of coronal peaks, sunspot reports, and important radio burst events are also communicated by telegram to the regional warning centers. Written reports are sent weekly, semimonthly, or monthly as is appropriate to the various subdivisions. Intermediate or preliminary publications based on these written reports are issued by the responsible data centers. Final publication will be made in the Quarterly Bulletin of the International Astronomical Union and in the Annals of the International Geophysical Year after careful review and compilation.

CURRENT STATUS OF DATA FLOW

The current status of the flow of data to world data center A and the interchange of data between center A and the other world data centers is set forth below for each subcenter of data center A. The situation differs widely among the centers largely in accordance with the time schedules set forth in the CSAGI guide and outlined in the previous section of this report. It may be noted that the flow of data most nearly approximates the CSAGI schedules in those disciplines in which there was some history of organized international exchange.

To date, world data center A has received data from 56 of the 66 nations participating in IGY. The larger nations, whose programs are extensive, are all included in the group transmitting data. These nations are: Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Burma, Canada, Ceylon, Chile, China (Taipei), Colombia, Cuba, Czechoslovakia, Denmark, East Africa, Ecuador,

Egypt, Finland, France, German Democratic Republic, German Federal Republic, Ghana, Greece, Guatemala, Hungary, Iceland, India, Indonesia, Iran, Ireland, Italy, Japan, Malaya, Mexico, Morocco, Netherlands, New Zealand, Norway, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Rumania, Spain, Sweden, Switzerland, Union of South Africa, Union of Soviet Socialist Republics, United Kingdom, United States, Uruguay, Venezuela, Vietnam Democratic Republic.

Airglow and ionospheric physics.—The amount of data received in airglow projects is small at present because processing is laborious. A few months of data have been received for five nations. Some data have been sent to and received from each of the other world data centers.

The flow of ionospheric data is immense. Data have been received from each of the other World Data Centers, and directly from many stations. Approximately 320,000 feet (61 miles) of ionogram film have been processed by the data center. The dispatch to other data centers of data received by center A is fully current.

To date, 14 requests for data have been received by the data center. Some of these requests were for an entire month of data. Several scientists have already visited the data center to work with the data on the premises.

In addition to the CSAGI 6-monthly catalog, an interim catalog of data in center A for airglow and ionospheric physics has been issued recently.

Aurora (instrumental).—Data from instrumental auroral studies are flowing more slowly than anticipated. More time has been required to process and reduce all-sky camera films and transmit them to the data center than was estimated in the CSAGI schedule. Nevertheless, at present film has been received from most of the cameras operated by United States projects, and from several South American stations.

Aurora (visual).—In the United States there are 424 active volunteer observers from whom 16,000 positive and 50,000 negative reports of auroras have been received. Twenty thousand positive and three hundred thousand negative reports have been received from the United States Weather Bureau. From these reports, over 1,000 auroral maps for 15-minute intervals have been drawn at the regional center at Cornell.

Data for the first 8 months of IGY have been dispatched to the other world data centers. Data have been received from the data center in Edinburgh. In addition, data have been sent directly to center A from Argentina, Chile, Cuba, Hungary, Mexico, and New Zealand.

Cosmic Rays.—Data are flowing regularly to data center A from centers B and C. Many stations send data directly to center A: to date, data have been received at center A from 20 of the 35 nations participating in the IGY program in cosmic rays. From the Soviet Union, data have been received from 5 stations; from 4 of them quite regularly. The data from the station in Moscow are sent in a printed journal which contains a considerable amount of additional geophysical data.

The flow of data in cosmic rays during the past 5 months has been more than 5 times as great as during the first 6 months of IGY.

Geomagnetism, gravity, and seismology.—Magnetic data have been sent to center A from nations in the Western Hemisphere for forwarding to the other world data centers. No data have been received directly from the other world data centers presumably because stations which send primarily to these centers send also to center A, usually through a collecting agency.

Geomagnetic data have been received from 71 stations in 28 nations, including 25 stations in the U. S. S. R. which are quite prompt in their transmittal. Geomagnetic data from the U. S. S. R. stations now in the United States data center include the first 9 months of IGY.

Many requests have been received for geomagnetic data, including requests for the data from the entire chain of variograph stations in the Western Hemisphere.

The flow of gravimetric data has been small as yet. The flow of data to world data center A includes earth tide studies at 3 stations in Japan and 1 station in Hungary.

Bulletins containing seismic data have been sent direct to data center A from stations or national collection agencies of 31 nations which are participating in the IGY program. The bulletins received to date include data from 156 stations, of which 49 are in the U. S. S. R.

Glaciology.—The flow of data to the center for glaciology has been limited to progress reports from glaciological projects in Canada, New Zealand, and the United States. The basic data from the field work accomplished during

the first Antarctic summer which ended in March of this year should be transmitted to the data centers within the coming 4 months.

Longitude and latitude.—Data from the two programs in longitude and latitude have been flowing to their respective primary data centers: astrolabe data to Paris, moon position data to Washington. These data will be reduced and published by the primary data centers. The flow of moon position data has begun only recently owing to delays in the commencement of the observation program.

Meteorology and nuclear radiation.—Most stations submit data directly to world data center C. Data from stations in the Western Hemisphere have been forwarded to centers B and C as required.

Center A has received data from 38 nations, including microfilm for 3 months of data from the U. S. S. R. data center. A similar amount of microfilm has been dispatched to the U. S. S. R. data center.

The flow of data to center A from the stations in the United States and North America alone amounts to 25,000 punched cards per day—for the entire world network of stations the data will require about 100,000 cards per day. These data will be reproduced on microcards by world data center C.

The pattern for the flow of data in nuclear radiation was not established until after the beginning of IGY. Center A has received data in nuclear radiation from 11 nations participating in this program.

Oceanography.—Sea level data from nine countries have been sent to data center A. Cruise reports have been received from 8 nations for cruises of 23 ships. Data have been sent to and received from the U. S. S. R. data center for oceanography. World data center A issued an interim catalog of data received prior to April 1, 1958.

Rockets and satellites.—The CSAGI guide outlining the operation of the data centers for rockets and satellites was issued in April 1958. Prior to this time, very little data had been received by this center, in large measure stemming from the nature of rocket and satellite results and the agreed-upon timetable: 12 months after completion of an experiment.

In order to make available to interested scientists the results of rocket and satellite launchings, data center A initiated 2 series of reports: 1 for rockets, 1 for satellites. Three issues of the satellite series have been published containing valuable preliminary data which could be made conveniently available in such reports. Some preliminary and informal reports have been received from the U. S. S. R., descriptive of their satellite experiments. Some preliminary reports on United States rocket and satellite firings are also now on hand and are being prepared for distribution.

Solar activity.—Data flow very promptly in this discipline. Center A has received data from 21 nations participating in the solar-activity program. In addition to the telegraphic data, written and tabulated reports are received regularly and promptly. Monthly final lists of solar flares are to be dispatched by the 7th of the following month. One such report from the U. S. S. R. was received by center A on the 10th of the month following the month covered in the report.

As part of the intermediate publication of data, center A has published Reports of Surges and Active Prominence Regions for the months of July, August, and September 1957. Several requests for data have been received. Most of these requests could be met by certain sections of these intermediate reports.

Dr. KAPLAN. We are now a little bit past the halfway mark in the IGY and I should like to point out a few of the highlights of the program and then my colleagues will talk in more detail and discuss the individual areas in which they are particularly interested.

INTERNATIONAL COOPERATION

This is an international program and one of the most reassuring parts of the program has been the extent of the international cooperation.

In my prepared testimony on page 2 there is a very simple and graphic picture of the way that has happened, related to the various key dates.

The first time that we appeared before you there were 26 countries participating. The second time we appeared before you there were

36 countries participating and the third time we appeared before you there were 40 countries participating. At the present time 66 countries with some 2,500 observing stations and more than 10,000 scientists are actively at work.

Mr. THOMAS. That is remarkable.

Dr. KAPLAN. I shall not mention the participating countries, but they obviously cover the entire surface of the earth.

RELATION TO SOLAR CYCLE

The key to the program, as you recall, was the planning to coincide with increased solar activity because of the role of the sun in many of the phenomena of the earth and its atmosphere as well as its oceans. This as well as many other problems marked the need for international cooperation and here the IGY World Warning Agency, which is operated by the National Bureau of Standards of the United States, with headquarters at Fort Belvoir, I think emphasizes the degree and the quality of the cooperation because regional centers in other parts of the world have the problem of daily sendings of status reports on the state of the sun, calling attention to recent solar and magnetic activity.

SOLAR ACTIVITY AT THE BEGINNING OF IGY

As luck would have it, the observation part of the program as you recall got off to what one could refer to as an explosive start when a major solar flare occurred. An alert was issued to warn people about it and a special world interval was declared on June 29, and the results of that are mentioned.

One of the major results of this occurred, as a date, on July 4, again, by strange coincidence, when a rocket was fired into the high atmosphere off the coast of California. This was possible because of the warning received by the warning agency to which I referred. This rocket sent radio signals through the ionosphere and the signals were received from the rocket and the well-known communications blackout that occurred during periods of intense solar activity was observed directly for the first time, so that guesswork went out as to the location of the ionization that causes radio absorption and the character of the radiation. So, instead of guessing as many of us have for previous years as to what causes it, it was found that the additional electron layer was caused by solar X-ray emissions, something that might have been suspected, but of course nothing like observing it.

UPPER ATMOSPHERE WORK

You will notice in my remarks and in many of the remarks of those in particular who deal with the upper atmosphere that the word "magnetism" occurs in conjunction with them and the electrical state of the high atmosphere.

Another field, the electrojet or the so-called equatorial electric current, is being explored as well as the related areas by the observation of whistlers. I think you recall on one occasion when Dr. Berkner wrote into the record the sound of the whistler phenomenon which in many ways is one of the first direct ways of exploring the

level outside of our own atmosphere. The results of this have been to disclose that the density at these very high altitudes is greater than we thought and the application of some of these experiments will result in the extension of the earth's atmosphere up to approximately 50,000 kilometers instead of stopping at 300 or 400 as we thought and go out into interplanetary space.

Our concept of the atmosphere and its relationship to the sun has been completely changed. These are preliminary but very indicative results.

In the field of cosmic rays on which Dr. Simpson will enlarge, once again new information about the magnetic field on earth and its immediate surroundings has been found.

HEAT AND WATER STUDIES

Now, going from the upper atmosphere to the general area of the low atmosphere—the heat and water of the earth—one of the notable results has come from an Antarctic study in which it has been found that at the South Pole for example, which is about 10,000 feet above sea level, there are 9,000 feet of ice beneath it. The Byrd Station sits on 10,000 feet of ice, far exceeding any original expectation, and only 5,000 feet is above sea level. The general results so far and our understanding of this Antarctic continent are, you might say, very, very enlightening. We are really surprised. It does not appear to be a single continent at all. The whole state of it is puzzling the people involved. At the earth's crust the entire structure of that continent in the interior instead of being a single continent now appears to consist of no longer a solid mass but there are ice mountain ranges, frozen fiords and vast frozen inland lakes. Dr. Wexler who will report for Dr. Gould, will undoubtedly enlarge upon this.

INTERIOR OF THE EARTH

One of the notable results—and I just mention one here because my colleagues will enlarge upon these—in the study of seismology is the development of a surface device for measuring the strength of the earth's gravitational field which enables us to obtain gravity measurements at sea—75 percent of the earth's area—by the use of surface vessels doing away with the use of submarines. This is much quicker and somewhat simpler.

IGY DATA

There are a number of other things. One of the vast areas of the IGY which we have to become proficient in is the interchange of data. As the program developed and the magnitude of the effort grew, the question of data interchange became very important. There is an appendix to my testimony and Mr. Odishaw who is Director of the IGY World Data Center will elaborate on that further. As you know, there are three major world data centers, ours which is A; the one operated by the U. S. S. R. Center is B, and a third one is the general center C. Mr. Odishaw has prepared a very extensive report on the character of this part of the program. The data centers are in operation and data is flowing. So we are in actual business in this area.

FUTURE GEOPHYSICAL WORK

Now, finally, I might like to say just 1 or 2 additional things. It is inevitable, as we have the responsibility for the planning and operation of the program of this scope, we look ahead and try to find out what it is that we have responsibility for and what the future will bring. In a number of fields the extraordinary opportunities that IGY will lead to have been recognized particularly in these new fields of polar research, the field of oceanography and the general area of rockets and satellites. In the first field, polar research and oceanography, there are international bodies which are already studying and planning for the future and international committees with which we have parallel committees in our own Academy. In the fall we hope that the International Council of Scientific Unions will set up a special committee for rockets and satellites and in one of these fields I think you are already familiar with the post-IGY effort in the Antarctic, because you have already authorized some funds for the continuance of the efforts with reference to this undeveloped country.

RESEARCH VALUE OF IGY DATA

Finally, I would like to point out the research, both analytical and theoretical, which will be conducted from this tremendous amount of valuable data that comes out of the IGY. Here we have what one might refer to as the knowledge reservoir. We certainly hope with the increased emphasis on geophysics, the increased recognition of the role of the knowledge of our immediate environment and the surrounding environment— and we already see signs of many new people coming into the field, as new, challenging, and theoretical opinion open up—that this will be carried on in the normal course of the handling of scientific programs although many of us certainly hope that this will be enhanced. However, if we are to really capitalize on the results of the IGY, we feel that a special and major effort is called for and this is what I would call a special coordinated IGY research program which is essentially short-range; that is, perhaps about 2 years. Second, it is inter-disciplinary in character, as against normal research which individual scientists do, and we have the need for interrelated fields. This is theoretical and is one of the extremely difficult fields.

Mr. THOMAS. Welcome aboard, Dr. Revelle. We have been talking about you, Doctor, and it is nice to have you here where you can defend yourself.

Dr. REVELLE. I am sorry. The TWA lost my baggage.

Mr. THOMAS. We will sue them for you, Doctor.

Dr. KAPLAN. Finally, you have already noted, I think, some remarkable breakthroughs that have occurred such as the recent report at the Academy on preliminary satellite results and the report in particular of Dr. Van Allen in the radiation zone of approximately 600 miles. When things like this occur it immediately excites the thinking of not only the people who have made the observations and who were thinking specifically of those single operations, but all the people in the field of geomagnetism and solar physics in the earth's atmosphere and so on. It is in this area that immediate work should be done in our opinion if major discoveries are to be made. This is the

field, which I repeat, that we refer to as the special coordinated IGY research program. This is a field that needs immediate attention and in which there should be no hiatus if American scientists are to participate in these major discoveries. This is the kind of a thing that is so peculiar in an area of science like this and it is essentially a part of our everyday thinking.

I might say that recently—since I am still paid by the University of California and I do show up on the campus—one of my friends, an expert in propulsion appeared with me. I gave the final program in a rather remarkable series of space technology and Dr. Porter participated in this. My part was to sum up and his part was to look into the future. He talked about what we call magnetism hydrodynamics which is essentially electrical and magnetic forces added to the conventional aerodynamics that we have been thinking of in the past years, and as he spoke I thought how appropriate it was that this new look into the future of the field of propulsion, for whatever it was worth and he was quite practical, was so close to the kind of problems that are puzzling us such as how the cosmic rays enter the earth and how they get through this complex magnetic field and what is the nature of the sun and its atmosphere. I felt here was a rather remarkable coincidence, without ever discussing it in any of our previous discussions, that we in a sense were possibly blazing the way for the next great phase of propulsion of aerodynamics. So, even to us who have been trying to dream of the future, there are occasional surprises and pleasant ones I might say.

With this, Mr. Chairman, if I may, I should like to introduce the first speaker on the program.

Mr. THOMAS. It will be a pleasure to hear from him. You carry on the program as you see fit.

EXTENSION OF IGY RESEARCH

Before he starts, may I inquire as to this: Is there any thinking, and if so to what extent, that this great experiment will be wound up at any particular time? I thought I detected a fear that these undevelpoed areas and the efforts which you are making in them will be brought to an end. They certainly should not be brought to an end.

Dr. KAPLAN. Certainly, the thinking would last for a long time in the normal course of research.

Mr. THOMAS. And that work will not end?

Dr. KAPLAN. It certainly will not.

Mr. THOMAS. And whatever it takes in the way of time and energy I know the scientists are certainly more than willing to develop it, and what it takes in the way of sustenance I certainly think this committee will go out of its way to take care of that.

Dr. KAPLAN. We certainly appreciate that, Mr. Chairman.

Mr. THOMAS. These great works will be carried out.

Dr. WATERMAN. One, of course, is the analysis of this data taken during this period which has come in pretty fast and the research which that leads to and then there will be the processing of research itself.

Mr. THOMAS. We have gotten the door open and have gotten one foot in the door, have we not? No one ever thought that you were going

to wind this thing up in 1 year or 18 months. You are just opening the door. This is a lifetime work which lies ahead of us. Is that right?

Dr. KAPLAN. That is certainly true.

The general pattern of the program is to first talk about the lower atmosphere and the earth and the upper atmosphere and related solar problems and then the rockets and satellites. If Dr. Revelle has caught his breath, we can start with him and if not, we can come back to him.

Dr. REVELLE. I should prefer you let me get my ears cleared up a bit before I start.

Dr. KAPLAN. Fine.

The first person I shall call on, then, is Mr. Field who is the chairman of our technical panel on glaciology and head of the department of exploration and field research for the American Geographical Society.

Mr. THOMAS. We shall be glad to hear from Mr. Field at this time.

THE IGY GLACIOLOGY PROGRAM

Mr. FIELD. Mr. Chairman, I would like to submit for the record my prepared statement on this subject.

Mr. THOMAS. Without objection it will be inserted in the record at this point.

(The statement referred to follows:)

IGY GLACIOLOGY PROGRAM

During the IGY, glaciologists and meteorologists of many nations are studying most known ice areas of the world, including both the great ice sheets of Greenland and Antarctica and a large number of valley glaciers from polar to equatorial regions. Ultimately, comparison of data accumulated through these worldwide studies will permit a better understanding of past and present epochal climatic variations. Moreover, implicit in an accurate knowledge of present trends are clues of future climates.

The United States IGY glaciological program being conducted in many parts of the world embraces several functional studies including the physics of glaciers, ice flow and deformation, the physical and mechanical properties of snow and ice, geomorphology, glacial geology, petrology, paleoclimatology and micrometeorology

United States studies are being carried out both in the Polar regions and in the subarctic and Temperate Zones of North America. All are closely interrelated with each other as well as with similar programs being carried out by other nations. In the Arctic and sub-Arctic similar observations are being made by Canada, Denmark, Sweden, Norway, Poland, and the U. S. S. R. In the Temperate Zone observations are being made elsewhere in the Alps by the various nations in the area: Switzerland, France, Italy, West Germany, and Austria; in the Andes by several of the South American countries; and in Asia by the U. S. S. R. and to some extent by India and Pakistan. In the Equatorial Zone observations are being made by Great Britain in central Africa, Peru, and Ecuador in the Andes, and by the Netherlands in New Guinea. In Antarctica, glaciological observations are being carried out by the 11 nations operating there.

The USNC–IGY glaciological program is the first coordinated and comprehensive approach to the study of glaciers ever put into effect by scientists of this country. It includes observations in the Arctic: in Alaska, Greenland, and the Polar Sea; in the sub-Arctic and Temperate Zones of Alaska and western United States; and in various parts of Antarctica.

Common to these programs are significant results. First, as never before there has been an opportunity for short- and long-term planning and a critical examination of the principles, techniques, and procedures; and an evaluation of the kinds of observations that should be made and practical locales in which to apply the various glaciological efforts. It has provided a means for far better integration and cooperation between scientists concerned with the study of glaciers from various points of view, and it has increased immeasurably the ef-

fectiveness of interdisciplinary cooperation, especially with the other disciplines concerned with the heat and water budget, meteorology and oceanography.

Because of the international aspect, cooperation in the field and exchange of information with scientists in other nations has been greatly enhanced. In the United States the IGY program has made it possible to train more field personnel in glaciological techniques and in operations on ice and snow of polar and alpine regions. The program has also given impetus to the development of equipment and instruments and of procedures and techniques for glaciological research in different environments.

An important byproduct of the IGY program of observations has been the establishment of an archive for glaciological data at the American World Data Center of Glaciology. This archive consists of photographs, surveys, field notes, and both published and unpublished reports dealing with glaciers in North America. These data constitute a necessary background for determining historical and current trends of glacier behavior in Alaska, parts of western Canada, and in Western United States.

CONTINENTAL UNITED STATES

Blue Glacier station

As part of the effort to determine the present pattern and magnitude of shrinkage or growth of glaciers in the United States, two teams of scientists are studying the Blue Glacier situated in the Olympic National Park. A University of Washington team is studying the mass budget of the glacier, the balance between the snow and ice accumulated and that lost by melting and erosion. This is primarily a study of glacial meteorology. A California Institute of Technology group is investigating the three-dimensional geometry of the Blue Glacier, its surface velocity, and the distribution of velocity with depth.

The station was established in June 1957 on the upper part of the glacier and has been operating continuously since then. This station is being operated in cooperation with the National Park Service with logistic assistance from the United States Air Force and the Coast Guard.

An important finding to date is the unexpectedly high precipitation in the area. Judging by records obtained during the first 6 months of operation, it may well be that the wettest locality in the continental United States is on Mount Olympus. In January 1958 snow accumulated on Blue Glacier to a depth of 120 inches with a water equivalent of 30.44 inches.

Seismic soundings indicated a maximum thickness of the glacier of 920 feet. Surface movement was measured along eight transverse profile lines across the glacier. Maximum movement was found to be about 5.9 inches per day. Boreholes were driven into the glacier to depths of 400 feet and 740 feet, respectively. Inclinometer surveys were made in each borehole and will be repeated for several years to come in order to obtain the distribution of velocity with depth.

Western United States

In other parts of the Western United States a number of glaciological observations are being made on a cooperative basis with the United States IGY program. These are as follows:

(*a*) South Cascade Glacier, Cascade Mountains: Programs of regimen, flow dynamics and hydrologic studies were initiated in 1957, sponsored by the United States Geological Survey.

(*b*) Cooperative studies of Grinnell Glacier in Glacier National Park by the Conservation Division of the Geological Survey, the Weather Bureau, and the National Park Service.

(*c*) Nisqually Glacier, Mount Ranier National Park: Stadia profiles, measurement of terminus, and movement studies on the lower glacier.

(*d*) Other observations of glacier variations will be continued in the Cascades and Olympic by air reconnaissance and photography.

(*e*) Stadia profile surveys and observations of termini by the National Park Service in various other national parks including Yosemite National Park.

ALASKA AND THE ARCTIC

Arctic glaciology during the IGY is concerned with the morphology, history, and mechanics of mountain glaciers, ice sheets, and drift ice, and with the influence of this great volume of polar ice on the meteorology, climatology, and oceanography of the remainder of the Northern Hemisphere. Synoptic studies of the fluctuations in mass of northern glaciers and Arctic sea ice are providing clues to past climatic changes and present trends. Study of heat and moisture exchanges across the sea ice and air ice interfaces, and of long-range and seasonal accumulation and ablation, are essential parts of this program.

Alaska: McCall Glacier

The McCall Glacier in the Brooks Range, the Lemon Glacier, near Juneau, and parts of the Alaska Range, are now being studied by United States-IGY glaciological teams. Work in progress on the McCall Glacier represents the first direct scientific study of an Arctic alpine glacier. With equipment and supplies air dropped by the United States Air Force, two camps have been established on the glacier. The main camp is in a firn region on the upper part of the glacier, about 8,200 feet above sea level, and the second camp is about a mile above the glacier terminus, at an elevation of about 6,000 feet. Two men at the high camp are engaged in snow stratigraphy, movement, and micrometeorological observations; two others at the lower camp are conducting surface movement observations and photogrammetric studies. A recent report from the project leader states that it has become clear that all significant snow accumulation on these glaciers occurs during the summer months.

Arctic drift ice stations program

The contribution of the drifting stations to the overall USNC-IGY glaciology program in the Arctic involves measurement of the annual mass budget of the Arctic sea ice and its relation to total accumulation and ablation at the ice ocean and ice-atmosphere interfaces, respectively. A determination is being made of the annual thermal regimen of the Arctic sea ice and its relation to the net energy exchange across the interfaces. Also being determined is the respective role of short- and long-wave radiation; the thermal energy of accumulation, condensation, sublimation, and evaporation; the molecular conduction of heat; and the turbulent transfer of heat in the energy exchange across the interfaces.

Accumulation and ablation of the upper surface of the ice pack is measured by the combined use of stakes to determine the rise or fall relative to a fixed reference plane within the ice floe, together with measurements of weight differences over given time periods, of vertical cores through the surface snow and ice.

Accretion or ablation of ice at the bottom of the ice pack are determined from a series of cores taken through the ice pack every 2 or 3 months.

Scientists at two locations in the Arctic basin are now making studies of the melting of the ice pack, the freezing of new ice, and the general relations between the state of the ice and the local climate. One of these stations, drifting station B, is on an "ice island" 7 miles by 3 miles in extent and about 140 feet thick. This block of ice was probably calved off the Ellesmere Island ice sheet many hundreds of years ago and has been circulating in the Arctic Ocean since, driven by the winds and ocean currents. This ice island, known as Fletcher's Ice Island, has been occupied previously by United States scientists in studies of the Arctic Basin. It is currently at latitude 79°54′N longitude 115°36′W, about 697.9 miles from the North Pole.

The second station, called Drifting Station A, is now located at latitude 85° 30′ N. and longitude 151°36′ W., 310.5 miles from the Pole. It is on the ice pack itself, on a floe a few square miles in area and only some 7 to 12 feet thick. Scientists there have noted that, during the past summer season, about 12 inches of ice on the upper surface has melted, while as much as 18 to 24 inches of new ice has frozen on the bottom of the floe. This observation will be placed in proper perspective when all the information on radiation from the sun, ocean currents, and temperatures of the air, ice, and oceans has been studied.

ANTARCTICA

Deep drilling

The deep drilling program was tested in Greenland during the summers of 1956 and 1957. In the later year a hole was driven to a depth of some 1,400 feet and cores obtained. Some modifications to the rig were developed and were sent to Antarctica during October and November. The drill rig and accessories weighing 26 tons, which had been unloaded from a ship at Little America Station in December 1956, were delivered to Byrd Station by tractor train on October 24, 1957. Over 15 tons of additional equipment and supplies were airlifted from New Zealand to McMurdo to Byrd Station during October, November and early December. A party of eight men to handle the drilling and the core analysis was flown to Byrd Station during November and early December.

Deep core drilling began on December 16 and the study of ice cores (4 inches in diameter) began on the 29th. After 42 days of operation, on January 26 a depth of 1,013 feet was reached and since this depth was the objective, it was decided to stop further drilling in order not to risk irreparable damage to the

equipment. Continuous cores were obtained down to 1,000 feet. Detailed stratigraphy is visible down to 350 feet, which indicates that average annual accumulation is about 7.9 inches of water equivalent per year.

A glaciological laboratory was excavated for storage and study of the ice cores. The studies include density, detailed stratigraphy, petrofabrics, microfiltration of melted sections of the core, thermal measurements and hole deformation. Photo records were also made of the visual stratigraphy to aid in the interpretation of the annual accumulation. Half of the core was retained in Antarctica for further study; the other half was returned to the United Stated for immediate laboratory analysis.

After completion of the hole the drilling unit was dismantled and returned to Little America Station by tractor train in February 1958. It will be operated there for study of the Ross Ice Shelf during the field season, October to December 1958.

Antarctic traverses

There have been 5 major oversnow traverse expeditions, several shorter ones, and 1 airborne traverse operation. These were originated from (i) Little America Station, (ii) Byrd Station, (iii) Ellsworth Station, (iv) Wilkes Station, (v) Amundsen-Scott South Pole Station, and (vi) NAF McMurdo.

The program of the major traverses included glaciological, meteorological and geological observations, seismic soundings to determine thickness of ice and character of subglacial floor, gravity measurements, magnetic readings, and surveying. Samples were also obtained for oxygen-sotope analysis. The procedure was to travel every second day an average of 30 to 35 miles and to make scientific observations on alternate days. In general each unit was manned by 4 to 7 personnel equipped with 2 to 3 Sno-Cats, each hauling a 2½-ton sled. Refueling was accomplished by aircraft at intervals of about 10 days.

Ross ice shelf traverse.—This traverse left Little America Station on October 24, 1957 and returned February 13, 1958, covering a total distance of about 1,450 miles in a triangular route: west from Little America Station to within about 75 miles of NAF McMurdo, then south to near the foot of Shackleton Glacier in the Queen Maud Mountains to 84°12′ S., 171°00′ W., then returning north to Little America.

Specific accomplishments were determinations of ice thickness, water depth, ice surface elevation, magnetic field strength, magnetic compass variations, seismic velocity change with depth, gravity observations, survey of mountain peaks and ranges, recording of water data and wind drift patterns.

The elevation of the Ross Ice Shelf was found to vary from about 90 feet near the barrier edge to about 380 feet near the mountain front with an average of about 215 feet for the 40 stations occupied. The thickness of the ice shelf was found to vary from about 785 feet to 1,050 feet, and the ocean bottom was found to be from 2,065 feet to 2,165 feet below the shelf surface. This would indicate that this part of the ice shelf is afloat. What were believed to be two small islands submerged by the ice shelf were found west of Roosevelt Island.

Traverse from Little America to Byrd Station.—On January 25, 1957 the traverse party assigned to Byrd Station left Little America following the established tractor trail to Byrd Station. Because of limited time, scientific observations were not begun until the inland ice was reached at about mile 200, but from that point were made through to Byrd Station at mile 643.8 which was reached on February 27. Ice thicknesses were found to vary from 1,970 feet to 8,200 feet. From March 3 to 13 a short seismic profile was carried out in the vicinity of Byrd Station which indicated a thickness of ice under the station of almost 10,000 feet.

The first part of the route from Little America to Byrd Station was studied on a subsequent traverse by the Little America traverse unit. The 4-man party with 2 Sno-Cats left Little America on March 24, 1958 and made periodic observations to mile 160 and returned on April 10. This completed the traverse observations begun in February 1957 at intervals of 30 to 35 miles from Little America to Byrd Station.

Byrd land traverse.—The traverse party left Byrd Station on November 1957 with 3 Sno-Cats. Following a northeast course for 248 miles a group of mountains was reached at 76° 25′ S., 112° 30′ W., the party then traveled east-southeast to the Sentinel Mountains and returned to Byrd Station on February 20, 1958 by a southerly, then westerly, route. Total distance traveled was about 1,180 miles.

Four major mountain ranges and a number of smaller mountain groups were sighted during the traverse. Several of these were visited for geological

samples and mapping. Among the samples collected were volcanic rocks and lichens. On the first leg the surface of the ice sheet varied from 4,215 feet to 5,937 feet and ice thicknesses varied from 5,166 feet to 9,282 feet. An important discovery was that bedrock on all except one stretch of 20 miles was found to be below sea level, the lowest being 5,068 feet. On the second leg, from 100 to 200 miles west of the Sentinel Mountains was found the greatest thickness of ice, 11,611 feet. On the Sentinel Mountains a former ice level was noted some 800 feet above the present ice surface.

An interesting find were penguin tracks at about 77° 32′ S., 98° 55′ W., a point over 150 miles from where the Walgreen Coast is believed to be. A skua gull was also seen near there. This may possibly indicate that the coast is much farther south than now indicated on maps.

Ellsworth station traverse.—A 5-man traverse party left Ellsworth Station on October 28, 1957. The route followed was south, past a heavily crevassed area to a mountain range 350 miles toward Mt. Hassage, and then return for 200 miles to a point about 225 miles southwest of Ellsworth Station.

At 80° 14′ S., 54° 15′ W., after having traveled 1,250 miles, the original party was returned by air to Ellsworth on January 17, 1958 and replaced on January 26 by a group newly arrived at Ellsworth.

This party with air support then carried out further reconnaissance work and established caches for the traverse in late 1958. Since crevasses almost surround Ellsworth Station, the vehicles were left on the inland ice for the next season's traverse and the party was flown back to Ellsworth Station. During February, 26 tons of supplies were cached at what is known as the mid-point at 81° S., 75° W., which is half way between Ellsworth and Byrd stations and where the original traverse routes from both stations were to be linked.

The seismic results disclosed the southern limit of the Filchner Ice Shelf, the presence of islands in the ice shelf south and west of Gould Bay, and of a deep trough 3,500 feet below sea level, extending southwestward into the heart of the continent.

A mountain range with 9,000-foot summits, 350 miles south of Ellsworth Station, was visited for the first time. Large ice free areas along the northern foot of the range were found. One valley had a fresh water lake 100 yards in diameter which contained abundant plant life. Four hundred pounds of rock specimens were collected.

Reconnaissance flights sighted mountains 120 miles farther to the south near latitude 84° S. On the northern leg of the traverse, peaks of 11,000 feet were seen at a distance. In the air reconnaissance to the mid-point cache, additional mountains were visible to the southwest and northwest, 2 large peaks were sighted to the west, and 2 ranges extended to the north. The mountains in this area have never been visited and it is doubtful if they have ever been seen from the air.

Wilkes Station.—Limited traverse operations from Wilkes Station were conducted with three weasels with small sleds. A means of access or ramp was found to the ice sheet and a route was worked out 50 miles inland (east-southeast of the station) to a point at 4,000 feet elevation on the ice sheet where a station was set up at what was known as Site 2 (S–2). Glaciological and gravity observations were made along this route, which was also surveyed. Glaciological observations including measurements of surface movement were made on Vanderford Glacier near Site 2.

Weasel trips were also made along the coast to study the ice cliffs of Clark Peninsula and elevated beaches on the Windmill Islands.

NAF McMurdo.—In February 1958 a seismic profile was completed across the head of McMurdo Sound from Hut Point to Cape Chocolate. Transport was by weasel and helicopter. The route lay over sea ice and over the lower tongue of Koettlitz Glacier, which was found to be afloat in water up to 1,970 feet in depth. The thickness of the ice, depth to bedrock, and glacial deposits were plotted and gravity and magnetometer studies were made. Water and ice samples for bacteriological and tritium analysis were also taken at a number of the stations.

Airborne traverse.—An airborne glaciological-seismological traverse was made in Victoria Land during January 1958. Three sites were visited by means of aircraft landings on the inland ice east of Royal Society Range and the Prince Albert Mountains. Stations A and B were in close proximity to the mountains at elevations of 7,750 and 8,300 feet, respectively. Station C was 275 miles farther west (350 miles from McMurdo Sound) at 77°22′ S., 139°48′ E., elevation 8,850 feet. The ice bottom reflections were not satisfactory, but a preliminary

interpretation of the records suggest an ice thickness at station C of around 12,500 feet.

Station glaciology

Observations of the physical properties of the ice sheet and of the glacial meteorology are carried out at each Antarctic station and in the surrounding area. These include, (i) establishment of a stake system for measurements of snow accumulation and movement; (ii) shallow and deep pits for studies of (a) stratigraphy, particularly the record of annual accumulation during past years, (b) density, (c) temperature profile, (d) deformation processes, (e) crystal analysis, and (f) for obtaining samples for study of radioactivity and for oxygen isotope analysis; and (iii) surface area studies to determine surface characteristics and the modifications which occur during the period of observation. Additional observations and activities are as follows:

Little America Station.—Ice shelf oscillation and deformation have been studied. Stakes were set up across "crevasse valley," between the station and barrier, to measure deformation.

An oceanographic program at the edge of the ice barrier was begun in Arpil 1957. Water temperatures have been obtained and water samples to a depth of 1,970 feet, as well as measurement of currents.

A deep pit was dug during the 1957–58 winter season to a depth of 65 feet and cores were obtained through the floor of the pit for an additional 70 feet. Density and compaction studies were made in a deep pit at Little America III, which had been prepared originally in 1940.

South Pole Station.—On December 5, 1957, a series of seismic shots were made which disclosed ice depth below the station to be 8,297 feet. Since the elevation of the station is about 9,200 feet, this places the subglacial floor about 900 feet above sea level.

A deep pit was dug during the 1957 winter season to a depth of 65 feet and temperatures, and cores were obtained. A micrometeorological program was begun in December 1957, and extremely informative radiation measurements were carried during the 1957–58 summer season. The average annual accumulation has been determined to have the water equivalent of 2.36 inches.

Ellsworth Station.—The ice shelf under the station has been determined to be 765 feet thick with the subshelf ocean depth of 2,620 feet. A deep pit was dug during the 1957 season to a depth of 100 feet, with an additional borehole to a total depth of 150 feet. A network of stakes was set up for the study of relative ice movements and barrier calving.

Wilkes Station.—At site 2 (50 miles south of the station on the ice sheet) at an altitude of 4,000 feet, a deep pit was dug to a depth of 115 feet, and a drill hole was dug an additional 85 feet. The movement of the nearby Vanderford Glacier was determined to be about six feet per day. Oceanographic and sea ice studies were carried out, and a survey begun of the ice margin and terminal moraines. An interesting find was raised beaches up to 100 feet above sea level.

Ross Ice Shelf deformation project

This project was concerned mainly with the measurement and mapping of deformed ice features of the Ross Ice Shelf between Roosevelt Island and the Bay of Whales. The base of operations, Camp Michigan, was established on November 20, 1957, at 163° 57.3′ W., 78° 34.0′ S. The camp site lay in the heart of a heavily crevassed area which was located by aerial reconnaissance in aircraft based at Little America Station some 32 miles to the northeast.

Four scientific personnel were stationed at Camp Michigan, and a geophysical team spent some 10 days in the area taking seismic soundings and gravity measurements. The camp was supported by helicopter from Little America and was established by moving equipment and supplies from Little America with tractors and sleds over a new trail established in November 1957.

The first phase of the study involved the establishment of a base line and triangulation network. Seventeen stations in an area of approximately 25 square miles were located and surveyed with a theodolite. Vertical aerial photographs were taken from an altitude of 5,000 feet, and large-scale topographic maps were made of selected areas so that details of change in the shelf ice surface could be recognized in future years.

Snow pit studies and examination of crevasse walls were initiated and carried out during the project. At a depth of 8 feet an ice band was discovered marking the melting which occurred during the 1952–53 summer. This melting was sufficient to provide free water which percolated downward through the older layers.

A density-depth profile from the surface down to 110 feet was made by sampling from the walls of an 80-foot deep crevasse at 3-foot intervals, and then drilling through the false snow bridge at the bottom to the 110-foot depth.

Several deformational features were recognized during the studies: (i) Ice anticlines produced by horizontal tensional stresses, (ii) the transverse crevasses lying across the anticlinal axes, produced by horizontal tensional stresses, and (iii) the products of shearing action. Thermal studies and meteorological observations were also made during the project.

Glacial geology

The Pleistocene glacial chronology of the McMurdo Sound region was studied during the 1957–58 summer season by a 2-man field party. One of the best localities where a record of advances of both the outlet glaciers from the icecap as well as the small alpine glaciers not connected with the icecap is in the ice-free area surrounding McMurdo Sound in the shadow of the Royal Society Range. McMurdo Sound is at the southwest corner of the Ross Sea at 165° E., 77° S.

The party spent 2 months in the field within 100 miles of NAF McMurdo. Logistic air support was provided by United States Navy aircraft operating out of McMurdo. Aerial reconnaissance flights were made with United States Navy de Haviland "Otter." Glacial deposits were examined on Ross Island, Black Island, Brown Island, Mount Discovery, Mount Morning, Mount Dromedary, and in the dry ice-free valleys along the west side of McMurdo Sound from Mount Dromedary on the south to Gneiss Point on the north.

Examination of the glacial deposits in the region revealed that both the alpine and outlet glaciers have fluctuated widely in the geologic past. The two groups of glaciers are now independent but in the past merged to fill McMurdo Sound with ice. At several times in the latter part of the Pleistocene epoch many large lakes formed when valleys were blocked by glaciers or glacier moraines. These valleys are now dry, but shorelines, deltas, lake clays, and evaporite deposits (mirabilite) remain to attest to the former existence and extent of these lakes.

A comparison of the present positions of the fronts of many glaciers with the positions of the same fronts shown in photographs taken 46 years ago reveals that very little or no change has taken place in this almost half-century interval. Adjacent to many alpine glaciers are small ice-cores lateral moraines about 100 feet high. These moraines are extremely fresh and may represent minute glacial advances of the last few centuries.

The latest major glacial advance of both outlet and alpine glaciers is represented by prominent extensive moraines and evidence of extinct, formerly ice-blocked lakes. The moraines are fresh, but ventifacts are numerous and well developed. Most alpine glaciers did not reach the sea at this time; however, the Koettlitz and Ferrar outlet glaciers pushed into McMurdo Sound.

Evidence of an earlier major glacial advance is present in the form of more extensive and slightly more weathered and eroded moraines. Ventifacts are very well developed and boulders are wind eroded. Two closely related glacial stages or stadials are present in this glacial episode. The huge outlet glaciers merged with the alpine glaciers to fill the southern part of McMurdo Sound to an elevation of about 1,000 feet.

In addition to the rather fresh moraines of these two later major glacial fluctuations there is evidence of a greatly older and more extensive advance of the Antartic icecap in the sound. High on ridges and flat areas above the moraines of earlier glacial advances there occur patches of weathered glacial drift. These glacial deposits are 2,000 feet or so above the valleys and have no, or little, morainal form. The boulders have been sliced off even with the ground surface by the ever-present wind. Ice of this stage filled all the valleys in the area and must have choked McMurdo Sound with ice that banked up at least several thousand feet high on the surrounding terrain.

Mr. FIELD. Mr. Chairman and gentlemen, I shall start in the middle. In this case glaciology really belongs between oceanography and meteorology. It is the study of the solar system as to its effect on water of the earth, and it is very closely allied on both sides with oceanography and meteorology which is the suspended water in the air.

GLACIOLOGICAL WORK BEFORE IGY

The International Geophysical Year has given us a chance to develop a program, the first comprehensive and coordinated program we have had in this country on the study of snow and ice. Up to World War II it was done on a more or less vacation basis by geologists and people who could go out and study the glaciers in the summer. World War II showed it was necessary, in order to operate over ice and snow, particularly in the north, to know about the physics of ice much more than just the spasmodic efforts made before.

Since World War II plans have developed which finally became crystallized in the IGY to make comprehensive studies. We are newcomers in this country to this in many ways. The Russians are oldtimers on this. They have snow and ice on their doorstep and have had it for a century or more and they have made very detailed studies as part of their economic existence. There are mountains in the south where the water for irrigating their lands comes from, and they have had to know whether that ice on the mountains was dwindling or increasing and, in other words, they have had to know its state of health. They have studied ice and snow for centuries, and we have come to study it lately here. We started with a shortage of personnel, and that is one of the things we have done during this first 11 months and one of the things we can point to. We have begun to train personnel in the study of ice and snow and how to handle problems in these areas. It cannot be done overnight. It takes not only theoretical study but actually living on the scene and working in these areas.

AMOUNT OF ICE IN THE WORLD

The old figures for the volume of ice on the face of the earth are about 3,240,000 cubic miles.

Mr. THOMAS. What was that figure?

Mr. FIELD. About 3,240,000 cubic miles. That may be 40 percent or so short now. We have found so much more ice in the Antarctic than was originally suspected, but in any case, that represents something on the order of 200 or maybe up to 300 feet of water if ever put back in the ocean. We are dealing with something which even a slight change of 10 percent in the amount of ice would make a difference, and 10 percent is something which the ice in the Alps and perhaps our western mountains have swollen in the last century.

Mr. THOMAS. Since Washington is about 4 or 5 feet above sea level, we could not even see the George Washington Monument; could we?

Mr. FIELD. Actually, we are dealing with something which is not beyond the realm of possibility in centuries to come—that a 10 percent change could occur—although so far it has not happened in the main bodies of ice.

These main bodies of ice have not shown this change which has been observed in the Temperate Zones where there has been a 10 percent shrinkage. That does not mean much over a fraction of an inch in fact at sea level but it will if Greenland, for instance, were subjected to the same change.

EFFECT OF IGY ON GLACIOLOGY

Our studies are divided into the Northern Hemisphere and Southern Hemisphere, but, before going into that, I would like to say, also, that this has given us a chance to develop techniques and work out procedures and work out the cooperation among the different groups that study ice. This is a little different from many disciplines. People who study ice come from various disciplines, such as ice scientists, meteorologists, hydrologists, and glacial geologists. All of these people have been brought together into a coordinated effort to study ice and snow. This has helped a great deal. It has also brought the glaciologists of this country much closer together, and the other people who study ice and snow in other countries. That has been a great advance. We have trained personnel, and we have developed instruments and procedures.

NORTHERN PROGRAM

The effort in the Northern Hemisphere is devoted to the study of glaciers in the western mountains. This has been done for some time through agencies such as National Park Service and the Geological Survey. They are concerned with the various aspects of the melting of ice and snow and in the growth of ice as it may relate to climatic change. Much of the water from the mountain ranges of the West comes into power stations, and much of the irrigation water comes from melted snow and ice, which has one great advantage in that your high water is in the summer, when your rainfall may be low. So, your reservoir of ice in the mountains has an extremely important effect on summer water operation. If there is a shrinking of the water supply, that represents a very serious matter, and must be known. Actually, it is of interest that, in the Northwest—in the Cascades, in the State of Washington, and the Olympic Mountains in the West, all a source of glaciers—the glaciers have been increasing in size in the last 5 or 6 years.

Mr. THOMAS. I note on the map that it is 3 miles long.

BLUE GLACIER STUDIES

Mr. FIELD. Yes, sir. There is a small glacier up there that lends itself to this type of study because it is small and compact. It is 2 or 3 miles long, and about so thick. You can take a body of ice like that, study all the properties of it, and then apply it to the much larger bodies of ice throughout the world, and you can get a general picture of it. Until you have mapped a small body, you are at a loss to know how to explain the movement and the health and behavior of the larger ice masses.

In the State of Washington, the Blue Glacier is being studied by a team that spent the winter up there. They have been there since a year ago, and will continue through until this fall. They have set up a station and are making meteorological observations every day. They have found that there is, possibly, the wettest spot in the western part of the United States. They are studying the movement of this ice, the rigidity, its structure and depth.

ALASKA STUDIES

Farther up the coast, this study is coordinated with the observation being made near Juneau in Alaska.

Then, there is a station on the northeast portion of Alaska on the Brooks Range, which is a polar glacier. This glacier is different from those in our Western United States in that the ice has a lower temperature—it is a few degrees colder. The properties of ice change very considerably with temperature and pressure. These things ought to be found out by long experimentation and study. A group established a station last year. They were there in November and came back in February, and they are there now making those studies—comprehensive studies—of the whole operation of this glacier. These have been tied up with the studies being made in the Arctic drifting stations A and B in the polar sea and in Greenland. Of course, the Russians are on the other side of the Arctic, making similar studies on the mountains bordering Siberia and Spitzbergen and those areas over there on the polar sea itself. These are all coordinated studies to determine what is going on up there.

The polar ice has been shrinking for the past half century, and the problem is to determine its relationship to the atmosphere above, and to determine the factors that are reducing the thickness of this ice. In other words, is it going on? If so, perhaps the Arctic Ocean will become navigable before the end of the century by icebreakers, or even the kind of icebreakers we have now. This is important to establish and, in order to do so, we have to have these stations making the observations of a detailed sort on the mountains bordering the polar seas, as well as on the icepack and the ice island itself. These studies are being made of the general behavior of the glaciers in Alaska, mapping them in very precise terms, so that in 5, 10, 15, or 20 years we can repeat flights over those glaciers with special camera equipment and rephotograph them and remap them to 5 meters contours so we can tell exactly what happened in the volume of that glacier—has it increased in size or decreased and in what way and the characteristics.

PAST CLIMATIC CHANGES

Other studies are being made to determine the past behavior of these glaciers and how they relate to the changes in climate—minute or major. We know that the climate has changed over the past 20,000 or 30,000 years very drastically. The problem is to know what is going on now and whether these minor changes will level off or trend toward another ice age or further away from an ice age.

ANTARCTIC STUDIES

In the Antarctic the studies are very similar and are the same type of studies in general that the other 10 nations are making in various parts of the area such as the measurement of ice and its thickness, where possible. That includes a study of the bedrock change and composition of the bedrock in order to get some idea of the geology down there from seismic reflections from the various soundings which are being made, and the nature of the surface of the ice. You cannot operate down there unless you know whether you can land and take

tractor trains over these areas. You need to know the surface features, how they change with the wind pattern, how new accumulations are formed, what are the accumulations every year, and what is the loss per year. All these factors have to be known. Camps have been set up where these studies are being made. We have stations in each of the blank spots of the interior.

Mr. THOMAS. Is this your map back of you here?

Mr. FIELD. Yes, sir. I can point these out to you. Byrd Station is here in the middle of this big area 5,000 feet above sea level.

Mr. THOMAS. How far is that inland?

Mr. FIELD. The Byrd Station is about 250 to 300 miles from the coast below. I must say no one knows exactly where the coast is here. The Byrd Station is 650 miles from Little America Station.

ANTARCTIC TRAVERSES

Now, out of all these stations, as well as Ellsworth Station on the west coast, we have had what we call traverse parties going out in light tractors or Sno-Cats which weigh about 3 tons and they draw a sled. They will provide food and fuel for about 10 days and then they have to be air supplied at 10-day intervals. Each group will vary from 5 to 7 men. They have geologists and seismologists, and some parties want to take meteorological readings and relay them back by radio to the main station. The geologists study the geology of the mountain ranges they encounter.

This Ellsworth Station found a mountain range in here and obtained a great many specimens. We have an open lake in here about 100 yards in diameter with plant life in it. It is important to establish how they got there and what its relationships are. They saw mountains all through here [indicating] and were able to map some of them. This party went up to a mountain range in here [indicating] and then across to another mountain range here, and at about this point [indicating] found the thickest ice yet, about 12,000 feet at this point. Each of these traverses were done in this last season. They started out in October or early November and got back in January or early February and each one went in the order of 1,200 to 1,500 miles.

ROSS ICE SHELF

On the Ross Ice Shelf a party went up this way and made this circuit and determined that this ice shelf flows back in here. It is a very thin floating mass of ice. Scott originally made the analogy that you could look at a piece of paper, and it is about the thickness in its relation to its area of a piece of paper. It is only about 1,000 feet thick and it extends back nearly 400 miles to the interior and about 400 miles across. Its structure is becoming known, but no one knows exactly how much there is formed from ice pouring in from the mountains around it and how much is just formed by the accumulation of snow on its surface.

It is moving out to sea several feet a day. Those figures are very hard to establish because there is nothing that you can tie it to, but in general Little America Station goes out to sea 5 feet a day. Since it is 2 miles from the ocean now, it's life may be a decade or a decade and a half. At Wilkes Station on the coast, a subsidiary station was

placed 50 miles inland on the icecap at 4,000 feet altitude and studies were made there. They do not have transverse equipment and do not have the long traverses and do not have the air support so that operations inland from there were limited.

At McMurdo Sound, which is the main logistical base, we made some studies out around that area of the geology. This mountain range here is very good for geological study, perhaps the best place in the Antarctic. Studies were made of the past history and behavior of the ice sheet; it has been thicker in the past through here. In various places on the mountain range, the ice has been up 800 to 1,000 feet higher previously and the dating of that is something that has not been possible up to now. We have some specimens and some organic matter that is being tested. The results have not——

Mr. THOMAS. May I interrupt you?

You have some dots on the map. They are labeled "U. S. S. R., Japan, Belgium, and France."

U. S. S. R. STATION

Mr. FIELD. Yes, sir; these are Russian stations established now. They penetrated as far as here in the interior. Both of these stations are higher than the South Pole Station. The South Pole Station is believed to be about 9,200 feet plus, or minus. You cannot see any land and there is no place where you know the exact elevation from there. Sooner or later we hope to get to these mountain peaks that can be surveyed. The Russians are here at eleven to thirteen thousand feet. This presumably is the highest part in the Arctic ice sheet.

Mr. THOMAS. How do they supply them?

Mr. FIELD. Tractor trains and they do have some air support. They do not have the massive air support, such as we have in the Globemasters. We do have planes in there more like our DC–3's, and perhaps a little larger than that.

Mr. THOMAS. They are at such a great distance into the interior I presume that the only way they could be supplied is by air.

Mr. FIELD. They also send up tractor trains which go with a great amount of tonnage. Byrd Station, for example, was supplied both by air and by tractor train.

Mr. THOMAS. Those Russian stations must be 500 miles farther inland than our Byrd Station?

Mr. FIELD. This station was just established in February. They were headed for the pole of inaccessability. They reached this point and stopped, and they are now living in wagons and in sleds. They do not have a permanent station there; it is going to be there until maybe September or October when they can either move on or go back. It is not a permanent station in the sense that we built our stations with buildings set up on the ice, or on the snow surface itself. They do have a station here as Vostok, which I believe is composed of buildings.

OTHER STATIONS

The other countries have not penetrated too far, and the French are in here 200 miles, near the magnetic pole and the British came across their track to the pole and to McMurdo. They made observations very similar to all of the observations we have made on these traverses.

LITTLE AMERICA

At the Little America Station we have had a small camp about 40 miles away where ice deformation studies were made, to study the whole change that occurs in this ice shelf as it creeps out toward the sea. That is, we try to determine what its age is, what its movement is, and how the ice is deformed. Ice in this sense is being studied as a rock. It is a rock that you can practically measure change in, whereas in the rocks you see in the hills, that perhaps may cover millions of years of formation, you cannot see the changes occur—you cannot measure them. In ice you can do that. You can see the change and you can measure it over a period of days, weeks, or months. In this case, it is a period of over 2 years. These studies have been mentioned in the report that is before you and I will not go into any more of that detail.

DEEP ICE TEMPERATURES

I would like to mention one interesting thing that comes from all of these studies here. If you burrow down about 25 or 30 feet below the surface of the ice sheet and take the temperature of the snow at that depth, you obtain a close estimate of the average annual air temperature above, so that you can go on to make these spot checks and get your general temperature reading in that area at that time. It is close enough to be of use. In these different areas, I have some of the figures that have come from these studies and that will give you an idea of this.

At the Little America Station the figure comes out to −10° F. At Byrd Station it comes out to −19° F. That is almost the same as at the center of the ice cap. At the South Pole it is −59° F. At Wilkes Station, S No. 2, it is −19° F. In other words, at 4,000 feet elevation here, it is almost exactly the same as 5,000 feet elevation here at Byrd station.

At station C in Victoria Land, which is about 350 miles from where we put a plane down and spent 6 days, it came out to −49°. That is at an elevation of 8,850 feet. That is an entirely new area nobody was in before, and it gives us a figure of what the average annual temperature, approximately, is at that point on the ice sheet. It is almost halfway to the Vostok Station.

Gentlemen, I think that concludes my report.

Dr. KAPLAN. I might mention, Mr. Chairman, that a number of our senior scientists have been to the Antarctic during these current operations. I think this is a good example of how the IGY has generated interest and excitement in the field, and I think I am safe in saying it is not one that we have paid enough attention to.

IGY METEOROLOGY PROGRAM

May I now call on Dr. Wexler, who is a member of the United States National Committee for the International Geophysical Year. He is the chief scientist for our Antarctic program, and he directs the meteorological research for the United States Weather Bureau.

I will ask him to report on the meteorology and the Antarctic programs, since, unfortunately, as I said earlier, Dr. Gould could not be present.

After that I will call on Dr. Revelle, whose ears should be open by then.

Mr. THOMAS. The prepared statement will be inserted in the record at this point.)

(The statement referred to follows:)

IGY METEOROLOGY PROGRAM

It is my great pleasure to appear before this committee and review for you the achievements of the meteorological work thus far in the IGY. All of the nations officially participating in the IGY have meterological programs, many of these nations have instituted special programs for the IGY or have established new stations to help fill out the pole-to-pole chains recommended by the CSAGI. Many countries also are making great efforts to achieve high altitudes for their balloon sounding program to permit more complete studies of the circulation of the highest parts of the troposphere and into the stratosphere. The establishment of new stations has had an important impact on knowledge of Antarctic circulation and the circulation of the entire southern hemisphere, as these areas had little or no meteorological coverage before the IGY.

The general work in the Antarctic and some special work, for example, study of solar radiation in snow or ice covered regions, have yielded some preliminary information that is new and promises to be most important. Most meteorological data, however, particularly those which are collected for the purpose of studying large phenomena like the general circulation of the atmosphere, are so vast in quantity that it takes months of processing and organization before they are even ready for study. Also, because of our many remote locations and communication problems, the timelag may be about 1 year between the collection of data and the completion of a set of data from all over the world, or one pole-to-pole cross section for a particular month.

Nevertheless, the first year of the IGY has achieved much in pushing ahead some of the frontiers of meteorology, and I should now like to describe for you some of these findings and achievements.

ANTARCTIC METEOROLOGICAL PROGRAM

In order to appreciate fully the results already obtained from the IGY it is necessary to recall the limits of our knowledge of Antarctica prior to the beginning of the IGY operations. No one had ever been more than 100 miles inland from March through September, and even in summer no location in the interior had ever been occupied for more than a week. With no previously coordinated effort to collect data, it was impossible to construct any kind of meteorological chart covering the Antarctic Continent itself. Also, certain types of important meteorological observations had never been made anywhere in Antarctica.

Cold pole of the earth

As a result of the relatively brief span of the IGY we now have much knowledge of the interior of the Antarctic Continent not even suspected before the IGY. For example, we now know definitely that the coldest part of Antarctica, and probably of the earth, is not the geographic South Pole, but a region about 400 miles from the pole in the direction of the west coast of Australia. The Soviet stations of Vostok and Sovietskaya are closer to this region than is the United States station at the South Pole, and therefore, they probably have experienced the record low temperatures of the world. In April of this year Sovietskaya reported a world record low of —109° F., and even lower temperatures may be reported before the return of the sun. The lowest temperatures on the continent are associated with the highest elevations and latitudes. Although no man has set foot on what may be the cold pole of the earth, its elevation above sea level is thought to be about 13,000 to 14,000 feet. The cold pole is the roof of the Antarctic Continent, and except for isolated mountain peaks, the snow surface seems to slope downward to the coastline from there. An important step in future Antarctic investigations will be a landing at this cold pole and an accurate determination of the snow temperature at a depth of 10 meters. This snow temperature will be approximately the same as the mean air temperature at a surface station, and it should represent the lowest average temperature anywhere on earth.

Antarctic circulation

At the IGY Antarctic Weather Central at Little America, maintained by the United States at the request of other countries, Argentine, Soviet, and United States meteorologists jointly studied the main features of the Antarctic atmospheric circulation. They found deep cyclones prevailing in the Ross and the Weddell Seas and an anticyclone, not of the shallow "glacial" type, but frequently extending upward to the lower stratosphere, located over the 12,000-foot-high ice plateau of East Antarctica. The additional IGY observations collected at Little America near a station first occupied by Amundsen in 1911–12, and later by the three Byrd expeditions, have for the first time in Antarctica revealed a significant warming trend of about 5° F., in annual temperature—or less than one-half of the warming trend observed in the Spitzbergen-Greenland portion of the Arctic during the same period. In the middle stratosphere, meteorologists found a classic polar cyclone with a strong jet of wind as fast as 150 miles an hour blowing from the west around the periphery of the continent. During October rapid heating occurs in the stratosphere with a complete reversal of the circulation to weak anticyclonic or light easterly winds by the end of November.

South Pole temperatures

In the Antarctic winter, absence of the sun causes a net loss of radiative energy to space, which combined with weak heat flow from below, permits cooling of the snow surface and overlying atmosphere. The snow surface, because it is essentially a black-body radiator, cools more rapidly than the atmosphere and so forms the marked surface temperature inversion, as much as 50° F. in the lower 1,000 feet, so characteristic of winter polar atmospheres. In a cloudless atmosphere the magnitude of the inversion depends on the relative speed of compensating heat fluxes—downward by turbulence and subsidence from the warmer atmosphere and upward by heat conduction from the warmer underlying snow and ice.

At the South Pole IGY Station, on May 11, 1957, at the time when the surface temperature fell to —101.6° F., conditions were optimum for maximum development of the surface inversion. No sunlight, a light wind of 5 miles per hour, no appreciable heat transfer upward through the thick ice mantle, all combined to produce an inversion of 60° F. in 2,500 feet. However, shortly thereafter, when a cloud layer moved in, whose temperature was no lower than —80° F., the increased downward radiation from this quasi-black-body radiator caused an increase of the surface temperature from—101.6° to —85° F. in 3¼ hours.

Summer (January and February) temperatures average —15° F., the highest observed being 6° F.

Seasonal temperature effects

As the sun slowly sets at the Pole, the temperature decline was extraordinary, averaging 1° F. a day, so that the average March temperature of —65° F. was 50° below the January average. In the next month the average temperature fell by only 5° and then an unexpected change took place. The May average temperature increased by 1° and even the June temperature was slightly higher than April's. This reversal of what was expected to be steady seasonal decline, reaching a minimum at or somewhat later than the winter solstice, occurred also at the Little America IGY Station, 800 miles to the north. But the behavior was not surprising at that location since 2 of the 5 earlier years of observation had shown a similar April temperature minimum and in the other 3 years the minimum occurred in May. The average Little America temperature curve, based on 6 years of data, shows the June average temperature is 4° higher than May's. Contrast this average Little America temperature curve with that Verkhoyansk, Siberia, where the annual temperature curve shows the classically sharp polar continental minimum occurring in January, 1 month after the winter solstice. Little America's coldest month, August, is 9° colder than June.

This surprising difference in winter temperature behavior at Little America and Verkhoyansk is caused both by the proximity of Little America to the warm open ocean, located in the early winter a few hundred miles to the north, and the frequent and intense winter cyclones in the Ross Sea which transport the warm air south across the coast in the interior of Antarctica. Later in the winter, when the halo of the newly formed pack-ice around Antarctica extends northward almost 1,000 miles, the warming effect of the ocean on air moving into Little America diminishes considerably, thus permitting the temperature to fall to the main minimum in August—2 months after the winter solstice. In north-

eastern Siberia, where Verkhoyansk is located, the prevailing circulation pattern is anticyclonic, with the winds blowing predominantly toward the ocean and not with a strong component from the ocean as at Little America.

The occurrence of this anomalous Little American temperature pattern at the South Pole was surprising since the pole is no less than 800 miles from open ocean heat and 9,200 feet above sea level. Here the maritime influence is exerted partially by means of clouds caused by the warm moist air brought in by the Ross Sea cyclones and forced to rise over the polar plateau. These clouds, acting as black-body radiators, reverse the downward plunge of surface temperatures by causing a net gain of energy instead of the net loss at the snow surface usually found in clear weather. But even in the absence of clouds at the pole, the warm moist marine air aloft, although not radiating as a black-body, can cause a rise of the surface temperature when the temperature difference becomes too large. Also the large winter increase in wind speed increases the turbulent transport of heat downward from the warmer atmosphere.

In the late winter when the open ocean is found nearly 1,800 miles away from the South Pole the marine air which does move into the Antarctic interior above the shallow surface layer of cold air, is colder than in early winter and so permits the surface temperature at the South Pole to drop to its lowest value of a −80° F. average for September and the −102.1° F. absolute minimum, a new world's record at that time, observed on September 17, 1957, just before the sun returned.

Seven of the eight stations in the Ross Sea area, coast as well as interior, and as far west as the Charcot and Pioneerskaya IGY Station, whose records are available for study, showed the same lack of the sharp winter temperature minimum with several peaks and valleys which is quite similar to that observed in the Arctice Basin and Greenland; the adjective "kernlose" or "coreless" had been given many years before by students of Arctic meteorology to this lack of sharp winter minimum.

In the Weddell Sea area, the Ellsworth (USA), General Belgrano (Argentina) and the Royal Society (Great Britain) IGY Stations each showed a sharp minimum in August, quite unlike the "kernlose" pattern found on the opposite side of the continent. In 1956, however, before Ellsworth Station was established, the latter two stations showed a marked "kernlose" pattern with minima in May and August. In 1955 the General Belgrano Station, the only one in the area at that time, again showed the "kernlose" pattern, with temperature minima in May, July, and September. The marked change in winter temperature patterns from 1955 and 1956 to 1957 may be a result of a large-scale dislocation in air circulation which affected that area, but not the opposite side of the continent.

IGY Weather Central

The establishment of the IGY Weather Central in the Antarctic made possible the collection and dissemination of Antarctic weather data which could be used for operational analyses and forecasting. Analyses and forecasts were necessary for the safety of the many aircraft flights which were carried out for the logistical support of the interior United States Antarctic stations.

The organization and operation of the Antarctic communications network between United States and non-United States stations required a very high degree of international cooperation. To obtain the weather data rapidly required the transmission of weather observations at least 3 or 4 times daily. The willingness of all stations to cooperate in transmitting current weather data made the operation of the IGY Weather Central possible.

The meteorological staff of the Weather Central during 1957 consisted of four American meteorologists, an Argentine, and a Russian meteorologist. All meteorologists participated in the work of the Weather Central. Presence of meteorologists from several countries was very helpful in the exchanges of weather techniques and facilitating weather communications. During 1958 the staff includes meteorologists from Argentina, Australia, France, and the U. S. S. R.

In addition to the routine Weather Central analyses and forecast program, studies were made of the movement of storms into the Antarctic Continent, of the monthly mean atmospheric circulations and blizzard conditions in the Ross Sea area.

Because of the great influence which this large region of ice and snow has upon the atmosphere as well as the large variation of solar influence at these high latitudes, the detailed structure of the storms over the Antarctic, at times, is found to differ quite markedly from those of middle latitudes. Basic differ-

ences between the Arctic and Antarctic circulation are becoming more clearly established and will be the topic of more detailed research studies.

Studies of the effects of the Antarctic Continent, in contrast to the effects of the Arctic Ocean, on the two hemispheres gives insight into the fundamental mechanisms which cause our weather.

The Antarctic serves as a large reservoir of cold air which may be injected into the middle latitudes. Warm air from middle latitudes may also invade the continent resulting in large temperature contrasts. The battle between the two contrasting air masses may go on for many days causing intense storms over large portions of Antarctica. Winds in the upper atmosphere can reach speeds of 200 miles per-hour. This knowledge is of extreme importance to any future air operations which may involve polar flights between the continents of the southern hemisphere.

ARCTIC METEOROLOGICAL PROGRAM

Because of its accessibility, much greater activity has taken place in the Arctic than in its Antarctic counterpart. Scientific exploration, principally in the fields of geography and oceanography, has been successfully undertaken over a number of years, but it was not until the first polar year of 1882-83 that a concerted effort was made by several nations to better understand the meteorology of the Arctic and to establish some standards for comparison with future work.

Unlike the Antarctic, however, the geography, and hence, the meteorology, of the two areas is substantially different. The Antarctic is basically a land mass surrounded by vast expenses of water. The Arctic is principally a water mass surrounded by continents.

Generally, the current Arctic meteorological effort can be subdivided into two major components. One of these is to aid in the study of large-scale physical, dynamic, and thermodynamic processes of the general circulation and a redistribution of energy in the atmosphere. The second is the study of the exchange of heat between the atmosphere, the oceans, and the continents.

Although it is true that there is some meteorology station coverage over the northern third of the hemisphere, there are very large areas that remain blank on weather maps. The Arctic Basin is one of these areas. To help fill this gap, two new geophysical stations were established for the IGY by the United States Air Force—Fletcher's Ice Island and station A.

Fletcher's Ice Island

Unlike pack-ice, Fletcher's Ice Island (Ice Island T–3) is a large tabular piece of ice about 9 miles long by 4½ miles wide by 140–160 feet thick. In addition to regular surface synoptic reports, observations are also made of solar radiation. Radiosonde observations are not made here because of the proximity of Fletcher's Ice Island to Ellsmere Island where a cooperative Canadian-United States station is in operation.

Surface temperature measurements made during the brief period of occupation of the Ice Island seem to support the estimate made by Professor Sverdrup of the absolute extremes of temperature expected on the Polar sea. His estimates were based on the records of the Maud expedition of 1918 to 1925 and the Fram voyage of 1894. In addition, he studied the reports of the few sledge trips made out on the sea ice. The lowest temperature recorded on Fletcher's Ice Island was —65° F., Sverdrup estimated the lowest possible temperature on sea ice to be —58° to —62° F. The highest reading on Fletcher's Ice Island was 44° F. compared to Sverdrup's estimate of highest possible just above freezing. It appears that, due to its thickness (150 feet), as compared to the thickness of the pack ice (8 to 12 feet) Fletcher's Ice Island has a local climate that is slightly colder than the rest of the ocean in winter and a little warmer in summer.

It was found that conventional aircraft operation was impossible during the thaw period of 1957. Many lakes formed in the troughs of the island's corrugations, and before runoff erosion produced drainage ditches, the total water cover was estimated to be about 60 percent. This estimate was based on aerial photos taken before rapid drainage began. Drainage ditches reached a depth of 8 to 10 feet. By the time of the fall freezeup the total water cover had decreased to about 10 percent. An interesting observation during the summer thaw was the reversal of flow of water in drainage ditches due to tile of the island in strong winds.

Solar radiation records for the past year are as yet unreduced, but it appears that the values of total solar and sky radiation during the past summer are somewhat higher than those determined in previous occupations. This

would account for the amazing loss of ice off the surface of the island during the thaw period. Ice ablation measurements were made at several representative points remote from the camp and showed a loss of up to 3 feet in places. The loss of ice in the camp area was much higher, due obviously, to contamination of the surface. The amount of ablation was underestimated in the planning of the camp buildings. Each building was provided with a skirt on each side which was to prevent melting of ice under the building. However, the entire surface of the island fell so much that the skirts were useless and discarded cargo parachutes were used around the buildings to retard the loss of ice. Even with this protection, the buildings were balanced precariously on ice platforms at the end of the summer.

Wiresonde observations for the determination of low-level temperature and humidity lapse rates were made during the dark season. All runs showed the characteristic inversion of the winter months.

IGY station A

To also help fill the gap in the Arctic Basin meteorological coverage, IGY station A was established on an ice floe about 700 miles north of Barrow, Alaska, and a full program of surface and upper-air observations maintained. Aside from the research value of these reports, these observations fill a current operational requirement in that they enable the daily forecaster to determine better the characteristics and motions of air masses in the Arctic Basin which, in turn, effect weather developments in adjacent areas.

In spite of its location, near 82° north latitude, IGY station A also reported considerable melting during the summer season. It was found, even with an average temperature slightly below freezing during the summer, most of the snow cover and about 11 percent of the old ice melted, and that about 30 percent of the ice floe was covered with ponded water. Some refreezing of fresh water pools under the ice and ponds on the surface subsequently followed, but this quantity has not yet been accurately determined. The thickness of the ice upon which station A is located averages some 7 feet. It thus provides an excellent location for the study of the heat exchange in the Arctic Basin between the ice-ocean, ocean-atmosphere, and ice-atmosphere interfaces. Through continuous use of data taken with radiation and other surface equipment, it is hoped to be better able to determine, over a long period of record, the heat budget and, hence, the net loss or gain of the Arctic icepack.

Wiresonde (ground anchored balloon) observations are also made on station A. It is interesting to note that some inversions, or warmer air overlying the cold surface, show the temperature at 100 feet to be some 18° C. warmer than on the surface. In the upper atmosphere, an unexpected low temperature of −85° C. was observed, which verifies the suspicion that under suitable conditions the Arctic stratosphere can become nearly as cold as the Antarctic stratosphere.

Value of Arctic meteorological information

The practical value of these Arctic stations cannot be overlooked. Reports from stations such as these would provide invaluable temperature and wind data for the increasing number of commercial aircraft using the top-of-the-world air routes. Also meteorological research may provide data useful for the establishment of emergency landing strips in the Arctic. The Russians have already proved the practicability of such landings, having made several hundreds of these throughout the period 1937–58. Our own Air Force has proved the feasibility of such runways, having established runways better than a mile long at both Fletcher's Ice Island and IGY station A.

Another interesting development at IGY station A has been the discovery of a submarine ridge in the Arctic, similar to the Lomonosov Range. It now remains to be seen how much influence this and perhaps other ranges have on the large, anticyclonic oceanographic circulation and, hence, the meteorology of the Arctic.

The potential value of Arctic meteorological findings and their application to the economic value of the Arctic is also of interest. If it could be determined that the Arctic is warming and that the pack ice is slowly diminishing, the economic impact brought about by water transportation media through a northwest passage would be considerable. Similarly, it is to our advantage to know the status of this Arctic heat loss or gain from a long-range economic development viewpoint.

Some preliminary estimates of the amount of heat perhaps from nuclear reactors required to melt the Arctic icepack have already been made in the U. S. S. R.

and the United States. More precise knowledge of the marine circulation, water volume and characteristics, and the meteorology of the Arctic is required, however, before serious consideration is given to such a possibility.

SOUTH AMERICAN COOPERATIVE STATIONS

As part of the IGY pole-to-pole chain of stations along the 80° west meridian, five upper-air rawinsonde stations were established in South America by the United States Weather Bureau and the South American meteorological services of Chile, Ecuador, and Peru. The United States supplied equipment and expendible supplies, translated into Spanish the operating manuals and instructions, and trained electronic specialists who were to be assigned to the stations. The South American countries supplied the sites and buildings and the observing personnel who were trained by the United States electronics technicians assigned. Dates of the beginning of the full programs at each station are as follows:

Quintero, Chile: June 3, 1957
Guayaquil, Ecuador: July 3, 1957
Antofagasta, Chile: July 17, 1957
Puerto Montt, Chile: Aug. 14, 1957
Lima, Peru: Sept. 30, 1957

Cooperation and interest of the meteorological and other officials of the countries concerned have been outstanding and the operation of these stations, besides providing heretofore unavailable information, is a great stimulus to scientific activities in the various countries.

In addition to research information on problems such as transport of heat, momentum, energy, and water vapor, the determination of the location of various jet streams, interdependence of circulation in both hemispheres, the data from the five IGY rawinsonde stations have already been of great importance to day-to-day airline operations. For example, in an unpublished manuscript by John Poulos, of Pan American Grace Airlines, Inc., entitled "The Severe Storm of December 7 and 8, 1957 Over the Santiago-Ezeiza Sector" it is stated: "It is the opinion of the undersigned that the IGY rawinsonde network paid for itself on the 8th of December 1957 by supplying timely and valuable information which helped us to better gage the intensity of a really severe Argentine storm." He also states that it was on the basis of this information that his company was able to take extraordinary precautions on conducting operations during the storm. In a second unpublished report by Maurice E. Graves, also of Pan American Grace Airlines, Inc., on "An Evaluation of Winds Aloft Forecasting Over Certain South American Route Segments Before and After Improved Upper Air Observations" it is shown that an average improvement in winds aloft forecasting of about 50 percent occurred after the IGY rawinsonde observations had begun.

This is a small sample of what might be the ultimate importance of the application of improved meteorological work fostered by the IGY.

STRATOSPHERIC METEOROLOGY

Because of the higher reaching balloons introduced during the IGY, daily North American weather charts of useful accuracy can now be drawn to give the day-to-day changes in the circulation at levels up to the 10-millibar surface (near 30 kilometers, or in excess of 100,000 feet). The 10-millibar chart has a special significance since it is well within the ozonosphere and near the lower boundary of the chemosphere. Thus, it will serve as a foundation for future studies of the higher, chemically active, layers. Also, it represents the wind flow at the top of the atmospheric layer in which nuclear debris such as strontium-90 travels and in which the latest type of rocket planes can fly. Properties of this virtually unknown portion of the atmosphere can now be ascertained practically on a daily basis.

Flow in the upper stratosphere is comparatively free of disturbance by orographic effects and lends itself to investigation of possibly thermally produced vertical expansions and contractions.

One of the mysteries of the stratosphere has been the exact nature, cause, and effect of the sudden warming first discovered in 1952. This warming, as much as 80° F. in 48 hours, apparently occurs each winter in the highest layers reached by the radiosonde. In 1957, intensive warming in eastern Canada which began on January 24, was followed a few days later by warming in the Kamchatka area—a simultaneity not heretofore known and which points strongly to the dynamic causes of these warmings instead of a direct solar cause as previously claimed.

While on the subject of the great changes of early 1957, it is perhaps worthwhile to mention a spectacular change which occurred in our national weather last year. As you will recall, the prolonged drought of 1952–56 in southern and central parts of the Great Plains was broken by the blizzards and heavy rain during both March and April of 1957; and during May there were disastrous floods in this region. The drought area shifted to the eastern and northeastern part of the country, where 1957 was the driest year on record at many places.

A striking meteorological feature associated with this change was an abrupt change of the mean jet stream at the 200-millibar level. Whereas, the mean jet was located near northern Mexico and southern Texas during the 3 spring months, in June it traversed the northern Plateau and northern Plains. This shift was reflected in displacement of the area of worst weather (tornadoes and floods) from the southern Plains during May to northern portions of the Plains and Mississippi Valley in June.

SPECIAL PROGRAMS

Ozone

Measurements of the total amount of ozone present in the atmosphere are being made at many points in both hemispheres. Special efforts are being made to collect data from the polar regions where our knowledge of this rare gas is limited. Measurements of surface ozone are also being taken in these regions.

Preliminary examination of the data indicate that even at high latitudes large amounts of ozone are present. According to the photochemical theory, ozone is formed due to the reaction of sunlight on the oxygen molecules in the upper levels of the atmosphere. But the data show that at high latitudes, both in the Arctic and Antarctic, ozone is present in the absence of sunlight during the winter night in quantities which exceed those found during the summer. Explanations to account for these ozone concentrations may be found in studies of large-scale atmospheric circulations and investigations related to the effect of the aurora on ozone formation.

Carbon dioxide

The study of the distribution of carbon dioxide in the atmosphere and the equilibrium between concentration of this gas in the atmosphere and oceans is a vital part of our understanding the heat balance of the earth. Carbon dioxide, although present in the atmosphere in small quantity (about 320 parts per million), is important because of its absorption and reradiation of heat energy in the form of infrared radiation. Our industrial civilization is pouring great quantities of carbon dioxide into the atmosphere and we do not really know yet what happens to it: how much is dissolved in the oceans, how much is taken up by plant life, and how much remains in the atmosphere. Previous measurements were too uncertain to compare with our new measurements; we are now establishing a new benchmark that can be used in the future to see how CO_2 concentration changes.

With the use of a specially designed instrument, carbon dioxide concentrations can be monitored continuously, and one instrument has been in operation at Little America throughout the IGY. A second is in operation at 11,000 feet altitude on Mauna Loa, T. H., and 5 others are operated by oceanographic institutions aboard ships, aircraft, and in laboratories. Many problems connected with calibration and intercomparison have yet to be solved but we do have some interesting preliminary information on the concentration of CO_2 in the atmosphere. It has been found that in air that is not contaminated by industry or civilization the concentration is remarkably constant, only varying by a few parts per million. Both Scripps Institution and the Lamont Geological Observatory have operated instruments on cruises and report that on long north-south profiles the concentrations are constant within a few parts per million. Some samples have been taken by using evacuated flasks in the Arctic and Antarctic and a program is being initiated to collect samples at certain selected land stations and along certain tracks of meteorological reconnaissance aircraft. The oceanographers have also recently perfected techniques to measure the CO_2 dissolved in ocean water.

Nuclear radiation

Several United States agencies are cooperating in taking air and precipitation samples and collecting radioactive material in the air to analyze and study as part of the international program in nuclear radiation. The application of such studies lies in the utilization of the tracer technique, which allows air

masses to be identified and their movements charted by observing the radioactive material, natural and artificial, carried in the atmosphere. This can supply information on the circulation unobtainable in any other way. In addition, since some of the radioactive material is introduced into the atmosphere at great heights, it is possible to study storage mechanisms and exchange between the troposphere and stratosphere. The New York Operations Office of the Atomic Energy Commission, the United States Public Health Service, the Naval Research Laboratory, the Geophysics Research Directorate of the Air Force Cambridge Research Center, and the United States Weather Bureau are cooperating in this program. Cooperative stations have been established at weather stations, airports, and United States embassies and consulates in many countries to collect samples. There are two main collection methods, which constitute the major part of the network program. They are the gummed film and air filter. The gummed film is a piece of paper covered with a sticky film and exposed to the atmosphere, so that dust or other particles falling down through the atmosphere will be collected. The films are sent to the New York Operations Office of the AEC for counting and analysis. The other method employs a fan which pulls air through a filter. The filter is changed and sent to the Naval Research Laboratory for counting and analysis.

This program is rather new in its application to geophysical problems, but the modest effort required will surely yield much important information.

Mauna Loa observatory

The IGY has assisted in the staffing and operation of the Mauna Loa Observatory, at an elevation of 11,300 feet, on the slope of the Mauna Loa Volcano, T. H., located 30 miles from the ocean, thousands of miles away from continents. Mauna Loa is the only accessible observatory at high elevation in the marine tropics. Because of the striking clarity of its atmosphere, Mauna Loa is a superb solar and astronomical site. The continuous carbon-dioxide observation will aid in determining the amount in the free atmosphere as well as determining the amount given off through vents in the volcanic cones. The ozone content of the surface air shows a strong diurnal variation of 15 to 20 percent, indicating an alternation of ozone poor air from below, flowing up the heated mountains during the day, and ozone rich air descending from aloft during the cooling of the mountains at night.

Earth albedo

Previously, reference has been made to measurements of the albedo of a snow surface, as has been done in the Arctic and Antarctic programs. By means of an ingenious instrument, called an albedometer, developed by a Frenchman, André Danjon, it is also possible to measure the albedo of the planet earth which determines the fraction of solar energy converted to atmospheric energy.

It may be recalled that when looking at the crescent moon the darkened portion of the moon can usually be seen, faintly illuminated by sunlight reflected from the earth. By means of the Danjon albedometer it has been possible to begin a series of measurements for this earthshine, which may be continued on an international basis for a number of years. The measurements are currently being made in the United States at White Sands, N. Mex., and at Yerkes Observatory, and elsewhere at observatories in Hawaii, Peru, Iran, Australia, and Japan.

More precise determinations of albedo values is one of the goals of earth satellite programs, and the albedo work accomplished by the Danjon technique during the IGY will assist in the interpretation of future observations from the earth satellites.

DATA PROCESSING

The programs already discussed indicate the vast amount of meteorological data being collected by the countries participating in the IGY, and also indicate how important it is to have a full and free international exchange of these data between countries. By international agreement three centers have been established to collect, exchange, and store IGY data. The United States operates one of these meteorological centers, known as IGY World Data Center A, at Asheville, N. C. This center collects all of the observations and measurements made by the United States stations, enters them on standard forms, and forwards copies to the other meteorological data centers at Geneva and Moscow. Included are surface and upper air weather observations, and measurements of solar radiation, ozone, nuclear radiation, albedo, and the chemical composition of the atmosphere. Data of other kinds which are too voluminous or too specialized

for widespread distribution are stored on punched cards or on microfilm and made available to scientists on request. These include the hourly observations and the autographic records of instruments at many stations.

Standard surface weather observations taken 4 times daily at over 200 stations, and upper air soundings (twice daily) at 140 United States stations are mailed monthly to Asheville, except from some of the outlying stations such as those in the Arctic and Antarctic. The standard surface observation consists of measurements of temperature, pressure, cloud type and cloud height, wind speed and direction, and 11 other meteorological elements. Each upper air sounding includes the level by level record of temperature, humidity, pressure, and wind up to heights as great as 100,000 feet. After being carefully checked for possible errors, these data are entered on punched cards so that further processing and use in scientific studies can be carried out automatically by machine. The next step is to make tabulations of the data in a standard format for shipment to the other IGY data centers.

Data from many other countries are also being received by the data center at Asheville. Some of these countries are Angola, Argentina, Austria, Chile, Hungary, Italy, U. S. S. R., and others. At the same time, all countries, including the United States, send their data to the data center at the World Meteorological Organization at Geneva, Switzerland. This is an outstanding example of international cooperation, for at Geneva, with the financial support of all WMO member nations, the meteorological data are being photographed in a completely standardized format and copies made by the microcard process. Thus, any scientists from any country can obtain all IGY meteorological data in condensed form. A 3 by 5 inch microcard contains, by a great photographic reduction, the surface data for 96 stations for 5 days, or the upper air data for 96 stations for 1 day; nevertheless it will require some 18,500 microcards to contain all of the IGY meteorological data.

The World Data Center A at Asheville will obtain several sets of the world microcards to complete its files of IGY data and to insure that the data can be quickly furnished to United States scientists.

It may be worthwhile to mention here that Data Center A has already received according to plan several months of IGY data on microfilm consisting of surface and upper air observations from Soviet land stations and ships. Further, the United States Weather Bureau recently received microfilm copies of U. S. S. R. meteorological charts for the war years 1939–41. These had never before been available and were sorely needed to complete gaps in the historical northern hemispheric map series, prepared as an indispensible part of our national meteorological effort.

IMPACT OF THE IGY ON METEOROLOGY

Certainly we have not been able to explain the vagaries of Northern Hemisphere weather based on study of Northern Hemisphere weather data alone. We are still unable to understand why last year there was a sudden shift from prolonged drought in the Southwest to copious and even flooding rains. We still do not know why this past winter was cold and snowy in the East but other winters were warm and open.

The expansion during the IGY of weather observing networks upward to much greater heights and laterally into unknown territory, particularly in the Southern Hemisphere and the Arctic Basin, offers new possibilities of studying and explaining these unusual and prolonged spells of weather which apparently are connected with worldwide dislocations of the normal wind systems.

The detailed observations of radiation from the sun during the IGY will enable meteorologists to see if unusual streams of solar energy can stimulate the upper atmosphere into turbulent motion which might generate storms and disturbed weather at lower levels.

Since 70 percent of the atmosphere rests on oceans we must learn more about the exchange of heat, momentum, water vapor, and chemicals between ocean and atmosphere; progress in this important field will be accelerated greatly by the expanded IGY oceanographic program.

Since glaciers serve as nature's own indicators of climatic trends and changes, the IGY glaciological program will assist greatly in establishing a firm chronology of past climatic changes which will assist meteorologists in understanding their causes and in predicting future variations.

In these and other areas the IGY is contributing significantly to the development of meteorology; in an 18 months' period we have compressed the development of an observational program which normally would require a generation.

This offers not only brighter prospects of understanding better what makes the atmosphere work, but perhaps also may lead to corrective measures to make the atmosphere work better for the good of mankind.

RELATION OF METEOROLOGY TO OCEANS AND ICE

Dr. WEXLER. Mr. Chairman, as Mr. Field indicated, meteorology occupies a connecting link between the glaciers and the oceans. For example, it would be impossible to lay down all this ice that Mr. Field talked about if it had not been for the atmosphere picking up the moisture and depositing it in the form of snow. Just to give you an idea of how long this would take, if you consider that the oceans contain 100 units of water, then most of the ice in the Antarctic contains 2 units. That is 2 percent of the amount of water in the ocean, and at any one time in the atmosphere there is only one one-thousandth of 1 percent of the amount of water that you find in the ocean.

The atmosphere being so tenuous cannot hold any more moisture at any time.

You see, if you are going to transfer water from the oceans by evaporation of the atmosphere and winds moving it to the Antarctic, this is going to be a very slow process. You can make some calculations, based on present air motions and the frequency of snowstorms, and it turns out to be between ten and fifteen thousand years, which would be required to lay down the amount of ice which we now observe in Antarctica. If you start from scratch and if you had no losses during that whole period, this gives you an example of how slow these processes are.

ICE AS A RECORD OF PAST CLIMATES

The ice also preserves within it a sort of a living record of past climates and at the Byrd Station a drill operation was carried on where temperatures and samples of air are obtained down to a depth of 1,000 feet where snow was supposed to have been laid down perhaps a thousand years ago. At that time and at that level, the temperature was lower than it was at the surface by 2° or 3°. It was falling as the temperature measurements were made, indicating that if you continue that temperature trend on downward, it cannot go down indefinitely, because there is a certain amount of heat coming up from the interior of the earth which heats the bottom of the ice so it has to stop falling at some point. It is possible to make some simple calculations based on the heat that comes up from the interior of the earth, and temperature measurements made in this big hole in the ice. This evidence seems to be pretty good to show that there is cold air in the ice that may have been laid down five to ten thousand years ago and that the climate was much colder, so we have frozen into this big Antarctic ice sheet a living record, so to speak, of the last ice age, which reached its maximum 10,000 years ago perhaps.

We have not been able to penetrate to the bottom of this ice sheet, but as you know there are plans ahead for continued research in the Antarctic and we hope that in the next year or two, we will be able to bore all the way down through.

ANTARCTIC TEMPERATURES

Mr. THOMAS. What was the temperature at 1,000 feet?

Dr. WEXLER. That was about what, Mr. Field?

Mr. FIELD. Minus 19.

Dr. WEXLER. That would make it minus 21; plus 2.

Mr. THOMAS. He told us that the temperature at 25 feet was minus 19 at Byrd.

Where did you take your soundings, at 1,000 feet?

Dr. WEXLER. That is right; minus 21 and the temperature was falling in between. If you went down deeper, it would be colder. The only way you could have gotten that cold was for that snow to have been laid down during a much colder period.

Mr. THOMAS. When do you think you will reach the maximum?

Dr. WEXLER. The maximum temperature?

Mr. THOMAS. Yes. What do your mathematical calculations indicate it will be?

Dr. WEXLER. It indicates that the minimum temperature, the coldest, was reached at about sea level or about a mile below that ice, where sea level is located. The mathematical extrapolation indicated that this would be the lowest temperature. It might very well be below that because we had to make certain assumptions about the temperature at the very bottom of the ice. We assumed that the bottom is just below the freezing point of ice and if it had been just 10 below the freezing point of the ice, the cold air would have been displaced by the colder side and down deeper in the ice.

Mr. THOMAS. Did you mention a figure in that connection? What was it?

Dr. WEXLER. If it were, let us say, 10 below the freezing point, let us say 22°, instead of 32°, then the temperature of the coldest layer would have been that much lower and would have occurred at a lower depth. Instead of a mile down, it would be a mile and a quarter down. This is speculation, and we would hope that in the future in our Antarctic work, we will be able to get really down to this particular area. Once you lay down a large blanket of ice—and it takes a thousand years for this to be laid down, and it preserves within it this record of climate—then the stage is set for the manufacture of cold air.

ANTARCTIC COLD AIR

Here in the Antarctic is the world's greatest refrigerator and it has already broken the world's record three times in the last year. This first occurred in May where for the first time in recorded meteorological history, the temperature went down to below minus 100°.

In September at the South Pole the temperature went down to minus 102½ below. The previous record was held by the Soviet Union in Siberia, where they had a temperature of 90 below. The Soviets have now regained the world record low temperature. This is shown by the red dot below the South Pole to the right, at an elevation of 13,000 feet, where they have achieved a temperature of minus 110.

As Mr. Field indicated, they did not have a very well constructed camp.

Mr. THOMAS. Mr. Field was not too far away from that, was he?

ANTARCTIC WEATHER CENTRAL

Dr. WEXLER. In a study of Antarctic weather, a weather central has been established at Little America, where we have had meteorologists from three different countries, the United States, Argentina, and the Soviet Union. This year, at this weather central, two additional countries have sent meteorologists—Australia and France. They have, for the first time, carried on an exploration of the Antarctic climate.

ANTARCTIC CLIMATE

This reveals certain interesting features. For example, when the sun goes down, the temperature falls extremely rapidly, perhaps, in the order of a degree of Fahrenheit a day for a couple of months, and until March it is about 50° or 60° colder than in January. Surprisingly, the temperature drop then comes to a halt, despite the fact that the sun is gone, and the temperature change starts reserving itself and it starts getting warmer. In the month of June, which is the winter solstice, the middle of the polar night, the temperature at the pole and in the logs of other stations may be a degree or two warmer than it was a month before. That is like saying in the Northern Hemisphere that December is warmer than October.

ANTARCTIC WINDS

This was a very unexpected bit of information, and it points out the fact that there must be a very thorough ventilation of the interior of the Antarctic area from the surrounding oceans, and that the winds blowing straight across that continent bring with them the heat that must be brought in to replace that loss by radiation to space. Some of these winds are extremely strong and, when you go up higher in the atmosphere, it is found in the stratosphere that we do not have that sort of exchange of air between the interior of Antarctica and the surrounding oceans. In the stratosphere, the winds are blowing, not across the continent, but across the edge of the continent, with winds of a speed as high as 150 or 200 miles an hour, which effectively prevent an exchange of air between the oceans and the interior, so that the stratosphere temperature is continuing to fall steadily. They do not go through this halt and rise, but the temperatures keep on falling. In terms of degrees, centigrade, it falls from minus 35° to minus 90°.

Mr. THOMAS. What do you get in the way of a wind at that altitude?

Dr. WEXLER. That altitude is about 40,000 feet. It blows from the west to the east around the Antarctic coast. When the sun comes back and the stratosphere warms up—it warms up because there is a little bit of ozone in the area—the stratosphere warms up from minus 90° C. to minus 40° C. in about 6 weeks, and the atmosphere, warming up, expands, and then, instead of a low-pressure area at the Antarctic, we have a high-pressure area and the winds reverse themselves. Instead of going from west to east, they go from east to west.

These have been some of the interesting things found out in this IGY weather station, where the meteorologists from these three nations have participated in this past year.

RELATION OF ANTARCTIC WEATHER TO WORLD WEATHER

The question is always asked, what significance is there to Antarctic weather to the weather of the rest of the world?

This is something that we have not been able to test before, because we have not had the observations before. Certainly, there has been very unusual weather occurring in the Northern Hemisphere in recent years. As you know, we had this tremendous drought in the Southwest which gave way to flooding conditions last year and which conditions have continued up to now. Meteorologists have not been able to explain why we have had these big changes in the weather pattern from one year to the next, based on examination of the Northern Hemisphere data alone. The information from the Southern Hemisphere, from Antarctic, will, for the first time, enable us to study these possibilities for this tremendous weather change that causes copious rains in the Southwest and very pronounced drought situations in the East at the same time.

The connecting link that we have between the weather deep in the Southern Hemisphere and the North, is the Pole-to-Pole lines of stations. These are set along the various meridians and along the 87th meridian. We have set up 5 new stations in South America which enable us to connect the weather events from the 2 hemispheres.

ARCTIC WEATHER

Meteorology is also concerned with the Arctic. Here, as Mr. Field indicated, there are some very interesting problems connected with the future of the ice in Antarctica. There is no question but that the ice has been decreasing in recent years and there have been all sorts of proposals to accelerate the melting of that ice. A Russian engineer has proposed numerous times in the past few years pumps powered by nuclear energy to pump warmer water into the Arctic from the Pacific at Bering Strait.

A conservative estimate would indicate that it would take at least 100 years to pump enough energy to cause that ice to disappear. Nature seems to be doing it on its own and it is of great interest to know whether this is likely to continue. At the pace it has gone on for the last few decades, if it does, it might on the one hand be a blessing from the standpoint of navigation and opening up a new area for ships to bring cargo in, and so on. But on the other hand, it may not be so much of a blessing when you open the Arctic Ocean, because it opens a big source of water and it may start big glaciers and the beginning of another ice age. On these Arctic icepack stations, we are measuring the weather, the temperature of the ice, how much of the ice is melting during the summer and increasing during the winter, and the temperatures of the oceans below in an endeavor to find out more about the future of that ice. Of course, the Arctic is a place where lots of cold air is manufactured, not as much as in the Antarctic because we have a warm flow below the thin skin of the ice, but enough to affect the weather in the temperate regions to the south.

OBSERVATIONS FROM HIGH ALTITUDES

The IGY has given particular attention to getting observations from greater heights. Formerly, our balloons would only reach, on

the average, about 40,000 feet. Now, we have doubled that and we are up to 80,000 feet because of the impulse of the IGY, and many of our balloons go over 100,000 feet. In so doing, they penetrate a very interesting layer where not much has been known. It is sort of a layer above the top of our balloons, but below the main area of interest for rockets.

HIGH ALTITUDE WARMING

These balloons revealed some very peculiar warmings that occur up in the stratosphere in the Arctic, warming that may be as much as 70° or 80° F. in 48 hours, which completely change circulation and may actually be the cause of circulation changes. Quite an argument is going on as to what is the cause of these warmings, whether they are due to sun radiation or particles coming down and warming up the atmosphere, or whether they are just a result of circulation changes on a large scale, for example, sinking of the atmosphere resulting in a warming. This is a whole new area of stratospheric meteorology. This will have practical benefits for aviation once we get up to these heights commercially and also it will have a very basic influence on the study of this unusual weather.

As I mentioned before, we have never been able to explain the unusual weather patterns that we have down below, based on Northern Hemisphere data alone and on one portion of the atmosphere. Now, for the first time, because of the IGY meteorological program expanded, we will have a much better opportunity to find out what are the causes of these unusual spells of weather.

NUCLEAR RADIATION

Another part of the meteorological program is the study of nuclear radiation. This is a comparatively new program and not as well organized as the other programs. There has been established a network, getting from several agencies air and precipitation samples, and collecting radioactive material to analyze and study as a part of the international program in nuclear radiation. For example, strontium 90 has been found in deposits of snow in the Antarctic showing that there is no barrier between the Northern Hemisphere testing grounds and areas deep in the Southern Hemisphere.

PROCESSING DATA

We have given a good deal of attention in meterology to the processing of data. Enormous amounts of observations in meteorology have made this necessary. We have developed a system of Microcards, little cards 3 inches by 5 inches. One of these cards contains all of the observations taken in the upper air from 96 stations. This is packed into this little card and put underneath a reader and then you get the data off in a very handy manner. The volume of data is so tremendous that it is estimated it would take 18,500 of these Microcards to hold all of these observations, despite the fact that one little card will handle the data from 96 stations.

MAUNA LOA OBSERVATORY

We have had very interesting observations at the Mauna Loa Observatory, on the big Island of Hawaii.

Because of the striking clarity of its atmosphere, Mauna Loa is a superb solar and astronomical site. We have extremely bright sunshine there and one of the brightest spots on earth, next to the South Pole. That is perhaps just as bright, or maybe a little brighter. As a matter of fact, at the South Pole in December you receive more sunlight than at any other place on earth.

About 90 percent of the sunlight at the South Pole is reflected back in space so that it does not warm things up too much, but on Mauna Loa the sun is very bright. The relative humidity is 10 percent and, in some cases, less than 1 percent; that dry air comes down from very great heights. During the day the circulation acts like a funnel and the air comes up from below bringing in moist air from the trades with a rather small ozone content.

We also are measuring the carbon dioxide content not only in the Antarctic, but on Mauna Loa. I know that there will be comments made about this later. Dr. Revelle will speak about that.

At Mauna Loa, this is of special interest because we are not only able to measure the carbon dioxide, but, when the winds change from a certain direction, we are able to measure the carbon dioxide as it flows out of the vents. Vulcanologists are extremely interested in knowing about this.

Mr. Chairman, I think that gives you a snapshot of what we have in meteorology.

However, I should say, and I know Dr. Porter will elaborate on this, I have not mentioned the satellite program. This will have a tremendous impact on meteorology because, for the first time, we have an observing platform which will be a global observing platform which meteorologists have wanted for many years.

Mr. THOMAS. Wonderful.

Thank you a million.

Mr. JONAS. Do you want to reserve time for questioning now?

Mr. THOMAS. I think now would be the time, Mr. Jonas.

Mr. JONAS. I believe that either Mr. Field or Dr. Wexler could answer this.

IGY COOPERATION

What cooperation or contacts do we have in Little America with the Russians? Do they visit our stations frequently or do they have personnel assigned there?

Dr. WEXLER. They have 1 meteorologist assigned to Little America and we have 1 meteorologist assigned to their main camp. They send in data several times a day, not only from their own stations but other stations which we cannot reach from Little America. There is the closest sort of contact scientifically. Once a week there is voice radio contact between Little America and the Soviet stations and other stations.

Mr. JONAS. We visit their interior stations?

Dr. WEXLER. Yes, sir; our meteorologist has visited 2 or 3 of their stations. I do not believe he has gone to the farthest one.

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Mr. JONAS. A temporary station that Mr. Field mentioned?

Dr. WEXLER. Yes, I think that is the only one not visited by our people. Winter closed in and it is difficult to get in and out of there.

Mr. THOMAS. Is that where the temperature was 110 degrees below?

Dr. WEXLER. Yes.

Mr. JONAS. That is all.

Mr. BOLAND. I think it would be well to have these interchanges. I think the process would be fairly simple for the interchange of information and also scientists.

Dr. WEXLER. Yes. The observations collected from all of the stations are funneled into Little America and then they send out weather forecasts and summaries of weather conditions observed.

ANTARCTIC LIVING CONDITIONS

Mr. THOMAS. How do our people live, eat, and sleep there?

Dr. WEXLER. They do very well. We summer tourists do not see the picture. I found the food good, but we are told that at the moment the summer visitors depart then they really get down to eating.

Dr. KAPLAN. Do you want to add something about Dr. Gould?

Dr. WEXLER. If we have finished with the meteorology, I can go on to the Antarctic phase.

EXCHANGE OF DATA

I should say that the data-exchange problem now finds us where we have received from the Soviet Union the first 3 months of the meteorological data in the IGY, which is very complete, and just as complete as the material we sent to them. They have done something more than that. The Weather Bureau has been drawing maps for the whole Northern Hemisphere each year, beginning in 1899. That is, this series was not actually started in the year 1899, but in World War II. The mapping was carried back as far as 1899 and there was a big gap in World War II because the nations stopped sending weather information. We have tried to fill that gap so as to have a 60-year record of maps in the Northern Hemisphere.

They have sent us weather information for these missing years, which enables us to fill this gap. The exchange of information has been extremely good and we feel that we are gaining in large extent.

WEATHER FORECASTING

Mr. JONAS. I would like to ask one other question.

Do they have a better or poorer record of forecasting weather?

Dr. WEXLER. Sir, that is very difficult to answer because I never really have been in a place where I saw the Soviet weather forecast keep a record.

Mr. JONAS. You forecast down there, you said?

Dr. WEXLER. Yes.

Mr. JONAS. Are they not forecasting, too?

Dr. WEXLER. Only for their local spot, which we do not see. We make forecasts of Little America for all of the stations.

Mr. JONAS. They use yours?

Dr. WEXLER. They use ours as a general guide and do their own local forecasting.

IGY ACCOMPLISHMENTS IN THE ANTARCTIC

If there are no more questions, I would like to go on to Dr. Gould's statement.

(The statement of Dr. L. M. Gould follows:)

IGY ANTARCTIC PROGRAM

It is a pleasure to appear before this committee again, and I appreciate the opportunity to report on the progress which has been made during the past year in the Antarctic.

This great continent of extremes, with its little-explored 6 million square miles sheathed in ice and snow, its 6,000 feet average elevation, its worlds coldest climate and its natural inaccessibility, is by far the most interesting and most challenging of all the worldwide areas which have been under scientific observation during the International Geophysical Year. As you know, to meet this challenge, 12 countries have built some 50 scientific stations on the coastline and in the interior of the Antarctic. Six of these stations, including 2 interior stations, 1 of which is located on the geographical South Pole, and 4 coastal stations, one of which is being operated jointly with New Zealand, were built by the United States.

I should like at this time, to acknowledge the outstanding achievement of the Navy Task Force 43 under the leadership of Rear Adm. George Dufek in successfully establishing the six United States stations and the accomplishment of the major complicated task of maintenance, resupply, and the successful provision of logistic support to the IGY program. This tremendous undertaking would have been quite hopeless without his unfailing and wholehearted cooperation.

Our primary scientific objectives in the Antarctic are the studying of temperatures and winds, the electrical, chemical, and magnetic properties of the Antarctic atmosphere; the thickness, temperature, and age of the icecap; the topography and seismicity of the underlying rock; new features of the surrounding oceans, and many other phenomena.

The agencies selected to carry out the United States program in the several disciplines are: Aurora and airglow, Cornell University and the USAF Geophysics Research Directorate; cosmic rays, University of Maryland and the California Institute of Technology; geomagnetism, United States Coast and Geodetic Survey; glaciology, Arctic Institute of North America; gravimetry, University of Wisconsin; ionospheric physics, National Bureau of Standards and Dartmouth College; oceanography, United States Hydrographic Office; rocketry, University of Iowa; meteorology, United States Weather Bureau.

You might be interested to know that over 10 tons of scientific data was transported from the Antarctic by ship in March of this year. Some required constant refrigeration and all of it received very special handling and was accompanied at all times by a senior scientist to safeguard it against possible loss or damage. The ships were met in the United States by special IGY representatives who supervised the unloading and assumed the responsibility of accurate accounting and delivery to the final destinations. I am happy to report that it is all accounted for.

Although a more complete account of Antarctic research, discipline by discipline will be possible after the data has undergone study, this brief preliminary account of some of the findings may be of interest. Other witnesses, who are presenting work in specific fields, can expand these summary accounts if you wish, but I should like to give you some of the most interesting highlights.

Aurora.—Preliminary examination of the auroral data already shows that auroral displays tend to occur on the same days over both the Antarctic and the Arctic icecaps. Also auroral arcs have been discovered in the Antarctic which frequently are alined in a north-south direction rather than along a circle of geomagnetic latitude. This orientation is most puzzling, since such arcs customarily extend from east to west along a circle of geomagnetic latitude as our theories about aurora postulate that they should occur. While we cannot yet explain the causes for these arcs observed in Antarctica, our scientists consider that further work on this phenomenon is most important as it may provide fun-

damental new information concerning the causes of aurora and the magnetic fields associated with them.

Cosmic rays.—In addition to the continuation of the important round-the-world cosmic ray measurements made aboard the U. S. S. *Arneb*, a land program was carried out at the Wilkes and Ellsworth IGY Stations. A count decrease of 5 percent maximum was recorded on October 22, 1957, from 0100 Greenwich mean time to October 23, 0400 Greenwich mean time in conjunction with a magnetic storm. A low count, detected on August 30, 1957, was correlated with a cosmic ray decrease in northern latitudes.

Geomagnetism.—Unusual solar emanations create disturbances in the ionosphere which lead to magnetic storms and radio blackouts. Now for the first time we know that these storms occur simultaneously, probably within a few seconds, in the Arctic and Antarctic and the same appears to be true for the aurorae.

Glaciology (oversnow traverses).—To study the properties of the great Antarctic icecap and other phenomena, 3 major traverses which traveled over a total of 4,000 miles were undertaken during the 1957–58 summer season out of the Little America, Byrd, and Ellsworth Stations. We have plans to extend this work during the coming summer period.

The Ross Ice Shelf traverse party of 6, led by A. P. Crary, used 3 Tucker Sno-Cats, each hauling a 2½-ton sled; supported logistically by Naval aircraft it covered a distance of 1,440 miles in 113 days. The principal objective was the study of the mass and volume, hydrologic economy, temperature, morphology, and structure of the Ross Ice Shelf. In addition, meteorological, magnetic, and gravity observations were taken.

The shelf extends more than 400 miles into the Ross Sea embayment from a point at the foot of the Queen Maud Range, about 300 miles from the South Pole. Its maximum width is approximately 500 miles, and it has an area of 160,000 square miles or about the size of California. The traverse was made along a triangular route—400 miles west along the shelf edge (lat. 78° S.), then 180 miles southeastward along the foot of the Queen Maud Range to the foot of the Liv Glacier and finally 500 miles north to Little America. The shelf thickness varies from 800 to 950 feet near Little America to 1,000 to 1,100 feet west of Roosevelt Island and gradually increases to 1,400 feet at the Beardmore camp. The shelf floats but is grounded at Roosevelt Island and probably other shallow areas. The ocean depth varies from 2,000 feet at Little America to 2,600 feet near Minna Bluff and then decreases south toward the Beardmore. A considerable rise in the ocean bottom was found at 83° 30′ S., 163° W. to 169° W. on which the shelf is grounded.

While the temperature at 30 feet in the ice at Little America is −10.1° F. (a few degrees higher than the average annual temperature because of the influence of ocean heat transported up through the ice), the ice temperatures along the route to Minna Bluff and to the Beardmore are 4° to 5° F. colder. But at the foot of the Liv Glacier the temperature was about the same as at Little America, 400 miles farther north. This surprising result is probably due to warm "Chinook" or "Foehn" winds blowing down the glaciers from the southeast. The Beardmore camp was farther away from the glaciers and so escaped the warming effect of the descending winds. Halfway to Little America the 30-foot snow temperature fell by 9° F. and here the snow was extremely soft and large grained, presumably caused by lack of strong winds. Even at this midway point in the shelf, the temperature increased with depth because of heat conducted upward from the warm ocean below the shelf.

The Byrd traverse party, led by Charles R. Bentley, covered 1,180 miles from November 19, 1957, to February 20, 1958. The route extended north-northeast from Byrd Station (80° S., 120° W.) to 76° 30′ S., 113° W. to an unnamed mountain 60 miles south of the Kohler Range (leg 1); thence east to the Sentinel Mountains at 78° S., 87° W. (leg 2); southwest to 79° 37′ S., 91° 11′ W., and then west to Byrd Station (leg 3). The purpose of the traverse was to determine the general nature of the ice and protruding mountains in Marie Byrd Land and in the Ellsworth Highland east of the Byrd Station. A year earlier, in February 1957, the traverse party had traveled along the 650-mile trail from Little America to the Byrd Station taking measurements of the ice thickness and properties on the Rockefeller Plateau.

Seismic reflection and gravity results have been combined to draw a cross section of the icecap from the Ross Ice Shelf boundary of the Rockefeller Plateau of the Sentinel Mountains. From the Ross Ice Shelf-Rockefeller Plateau

boundary to the end of leg 1 the picture is generally the same. The underlying topography is Alpine, the ice thickness varying between 2,000 and 9,000 feet. All but a few peaks of the rock floor are at present below sea level; the major portions are far enough below to be under water even if the ice were removed and the land allowed to rise into isostatic balance. In this region, the depths to the rock floor computed from seismic and from gravity data are in good agreement. On leg 1 which is presumably more or less in the direction of ice flow, there appears to be a definite inverse relationship between ice thickness and surface slope, in accordance with theory.

Leg 2 shows quite a different picture, with a smooth bottom, great ice thickness (from 7,500 to over 11,500 feet), and broad gravity anomalies. Near the middle of the leg, the rock floor reaches a depth of 6,500 feet below sea level at a point where the elevation of the surface is a little over 5,000 feet.

The underlying rock along leg 3, southwest and then west from the Sentinels, shows a still different character—surface being very rough and mostly above sea level, in several places breaking the ice surface to form nunataks. Subject to further examination of rock samples this evidence indicates that the Sentinel structure extends southwest at least as far as 80° 30′ S, 98° W.

Fresh penguin tracks were found at a distance of over 150 miles from the nearest coastline. It has generally been accepted that penguins do not stray far from the seacoast. Does this discovery indicate the near presence of water far inland on the Antarctic continent? We hope to find the answer before the end of the IGY.

One hundred miles east of Byrd Station, ice 14,000 feet thick was found resting on a rock bed 8,200 feet below sea level. This is believed to be the thickest ice layer measured anywhere in the world.

The Ellsworth traverse, combining the types of studies made by both the Ross Shelf and Byrd traverses, investigated the Filchner Ice Shelf and the inland ice of Edith Ronne Land. In addition to glaciological studies similar to those conducted on the other traverses, the Ellsworth party also investigated mountains and rock outcrops in and near its route of travel, took meteorological observations for transmission to the IGY Antarctic Weather Central at Little America, recorded surface elevations and ice thicknesses, and observed magnetic declinations. An important goal of this traverse was to occupy a point that could also be reached by the Byrd Station traverse of 1958–59, thus providing a link across which data could be correlated.

The traverse party, led by Edward C. Thiel and Hugo A. C. Neuburg, left Ellsworth Station on October 28, 1957, traveled 1,250 miles in 81 days, and used equipment and vehicles of the same types as used in the other traverses. The party had been held up several days while air reconnaissance was made to find a safe passage through the heavily crevassed area existing in the first 50 miles south of Ellsworth Station. An apparently crevasse-free passage, involving a 65-mile detour to the southeast was found.

The party deviated about 120 miles from the planned route to make geological studies and collect rock specimens at a newly discovered mountain range at 82° 30′ S., and between longitudes 50° and 54° which may be part of the Pensacola Range; it is estimated to be 9,000 feet high in places, is about 450 miles from the South Pole and trends northeast-southwest throughout its length of about 25 miles. Black stratified bands were noted high on the mountains, and a 5,000-foot escarpment was discovered on the southern side. Evidence of mineralization was present in abundant green malachite stains. Some of the bright green stains were visible at 100 yards. No definite ore minerals of commercial value were identified in the the field, although 400 pounds of rock specimens were collected for thin section study and laboratory analysis. The specimens were tested aboard ship for radioactivity with negative results. Large ice-free areas were also found along the northern foot of the range near 82.5° S., 52° W. One of these dry valleys contained a fresh water lake about 100 yards in diameter, partly ice free, caused undoubtedly by melting of snow in contact with the dark ground which heats rapidly in the brilliant sunshine. The lake contained abundant plant life, and specimens were collected for botanical analysis.

A 2,500-foot high, ice-covered island extending for about 230 miles south and west from Gould Bay was discovered. Seismic soundings near its eastern extreme showed the land surface beneath the island's ice mantle to be at about sea level. Other islands, whose contours were not fully delineated, were seen still farther westward.

The traverse was hampered by crevasse fields along the route and finally, in early January, it was halted by an impassable field at 78°40′ S., 69° W., and shortage of gasoline. The traverse backtracked 200 miles to within range of the

supporting aircraft and was evacuated by air after a traverse of 1,250 miles that covered a large portion of the Filchner Ice Shelf and considerable inland stretches.

Under the ice shelf a deep trough was detected extending inland from the vicinity of the Belgrano Station, located 35 miles east of Ellsworth Station. The bottom of the trough averages from 3,500 feet below sea level. After heading southward from Belgrano for some distance, the trough swings southwesterly, passing between the island and the new mountains. It continues beyond the southerly limits of the traverse.

Further work is necessary before it can be said whether this trough extends all the way to the deep ocean basin discovered in Marie Byrd Land and thence to the Ross Sea. The planned traverse to Byrd Station next summer will contribute greatly to the solution of this problem. Since the depth to rock on the west side of the island is relatively shallow, a division of Antarctica into east and west on the basis of topography would most logically follow the axis of this trough. Thus Ellsworth might be said to lie in west Antarctica.

Glaciology (station).—At the Byrd Station, where the ice is 10,000 feet thick and extends 5,000 feet below sea level to the bedrock, a 4-inch core has been obtained to a depth of over 1,000 feet, at which level the ice is estimated to be a thousand years old. Below a temperature maximum found at a depth of 150 feet, the temperature decreases about 2° F. to the bottom of the hole, indicating perhaps a cold residual of the last ice age. The cores taken at various depths will be subjected to physical, chemical, and radiochemical analyses to determine age, crystal structure, and air temperature at the time of formation of the precipitation. Pollen and volcanic horizons will be sought to aid in the age determination. Snow density, grain, and crystal sizes will be measured.

At the South Pole Station a snow mine, 280 feet long, dug at a 20° incline angle with the horizontal, served the double purpose of providing melt water for the station and data for the glaciologist. At its deepest point the mine was 90 feet below the surface. In addition, a number of shallow snow pits were dug to note the horizontal variation of crystal structures and density. Hoar frost, deposited on the snow surface by the water vapor in the chilled air, was examined as were the sastrugi, or wave-like structures carved in the snow surface by the winds.

At the Wilkes Station 30 stakes were placed in the ramp area to measure ablation. Accumulation stakes, set out in February 1957 along a 25-mile due-east profile, have been measured. Studies at points along the trail leading to the icecap station, 50 miles away at an elevation of 4,000 feet, included mean annual air temperature, density, stratigraphy, and snow hardness profiles. It was possible to distinguish annual layers. Ice cliffs to the north of the station have been studied; no movement was found when compared against the terminal moraine. The ice deformation tunnel at the icecap station has been remeasured and the horizontal closure found to be negligible but vertical closure is as much as 1.5 inches. The glaciological deep pit was excavated to a depth of 115 feet; a handdrilled hole at the bottom has extended the depth to 200 feet and density measurements at the bottom gave high values up to 0.90. The flow rate at the center of the Vandeford Glacier has been confirmed to be approximately 6 feet per day.

At the Byrd Station the influence of the 1957 winter and subsequent summer on snow temperature was detected at depths of 26 and 52 feet, respectively. In September after return of the sun, warming was detected to a depth of 13 feet. A core was taken from the bottom of the deep pit at 40 and 100 feet depths for observations of density and stratigraphy. Entrapped air samples were taken from the ice at a depth of 100 feet. Melted cores were filtered to obtain precipitate material.

Oxygen isotope samples from the deep pit represent an estimated 2 complete year accumulation. Tritium samples from the top, center, and base of the deep pit each represent a year's accumulation layer.

At the Ellsworth Station the deep pit slopes 15° from the vertical, with a vertical depth of 100 feet. A 3-inch core hole was cut 85 feet below the floor of the pit 10° from the vertical. Ice from the deep cores show elongated bubbles of preferred orientation. The density of the deepest core was approximately 0.89. Temperature readings were taken at 11-foot intervals throughout the depth of the pit and core holes. Thermometers were placed 10 feet into the wall for pit measurements. The measurements show decreasing temperatures with depth which appear to approach a lower limit. Samples for oxygen isotope analysis were taken of the strata from the surface down to depths of 66 feet.

Spherical micrometeoritic particles 5 to 50 microns in diameter were collected from the snow which, in amount, agree with the estimated some million tons a year gained by the earth. Their number and size increased sharply on October 23, presumably due to an Orionid shower.

At Little America, the deep pit was finished at a depth of 66 feet. Cores were obtained at depths of 66 to 132 feet with hand augers. The approximate ice temperatures at various depths were: 55 feet, —9.9° F.; 85 feet, —8.7° F.; 130 feet, —8.0° F. This increase of temperature with depth is caused by the conduction of heat from the warm ocean below the 800- to 950-foot thick ice shelf. The gain of heat at the top of the shelf, however, is only 1 percent that of the average loss to space by radiation and so does not serve to ameliorate the climate very much.

The barrier or edge of the shelf near Little America moves seaward about 5 feet a day. Stakes have been located across two ice valleys for movement rate studies. Precise measurements made in February 1958 by A. P. Crary across Crevasse Valley between Little America and the barrier showed that the 11,500-foot long line laid out 375 days earlier had stretched 14 feet; this confirmed earlier observations showing the valley is widening and its underlying ice is becoming thinner. During a blizzard on August 30, 1957, the following results were observed from 70 accumulation stakes: 34, erosion; 14, no change; 22, accumulation; average one-third-inch erosion. One hundred sixty-five samples for oxygen isotope studies were taken at depths of 50 to 63 feet.

Meteorology.—Many remarkable and important effects are emerging from our program in meteorology. This is a very important field of research in which I have taken particular interest. I can touch only upon the highlights of many things which Dr. Wexler has brought particularly to my attention.

We, of course, knew it would be cold in the Antarctic especially at the 9,200-foot high geographic South Pole Station. Ed Flowers, the chief meteorologist, was not surprised by the —59° F. annual average temperature nor by the —102.1° F. minimum temperature, but was astonished to find a consistently strong breeze of 10 to 20 miles an hour accompanying these low temperatures—a chilling combination not previously observed.

Although the South Pole Station was the coldest of all the United States—IGY stations it was not so consistently miserable, meteorologically speaking, as was the Byrd Station located at 5,000 feet above sea level in the midst of Marie Byrd Land. There, Wesley Morris, the chief meteorologist, found the average temperature in 1957 was —18° F. with an absolute minimum of —71° F. and a maximum of +25° F. But the wind speed averaged near 20 knots from the northeast, with a maximum speed of 70 knots. Visibilities less than one-fourth mile occurred 2 days out of every 3. The number of clear days ranged from 15 in May to none in January and February. Station pressure ranged from 833.1 millibars in May to 775.5 millibars in July with many violent storms moving in from the Ross Sea. The strong winds and heavy snow often created violent electrical discharges from exposed metal.

By comparison, conditions at Little America seem less severe, and those at the Ellsworth Station are comparable to Little America. Somewhat less extreme temperatures are found at both the McMurdo Sound Station and at Cape Hallett. The Wilkes Station has been jokingly referred to as being in the "banana belt" of Antarctica, because the minimum temperature reported there was only —27° F., a low which has been exceeded in Nebraska nearly every year.

However, strong winds have been a problem at both the Hallett and Wilkes Stations. Storms have caused some damage at both. This year, on one occasion, hurricane winds, with gusts to 130 knots were reported at Wilkes.

At the Little America Station the regular meteorological program was augmented by special observations carried out by Ben Harlin, chief meteorologist. Ozone content of the surface air was recorded continuously by a chemical device designed at the University of New Mexico and to everyone's surprise revealed values in winter 25 to 30 percent higher than in New Mexico. Since ozone is manufactured naturally only in the sunlit portion of the lower stratosphere, this means that there must be an infiltration of air to Little America from the north and from a height of 10 to 15 miles. Now meterologists must find out how this is done.

For a number of years there has been much scientific speculation regarding whether or not precipitation falls in the vicinity of the South Pole. Obviously there is a source for the central polar icecap and for the ice eventually lost at

the perimeter of the continent in the form of bergs. But meteorological evidence indicated that the interior of Antarctica was always covered by a large area of relatively high atmospheric pressure, and therefore the usual precipitation processes would not be expected to occur. Curious theories were advanced to account for the snow, including suggestions of wind transport or direct sublimation from the chilled air.

Now we know for the first time that the general concept of the relatively high pressure is incorrect: there is light precipitation at the South Pole and the processes which produce it are not unusual. Low pressure systems, or cyclonic storms, pass near enough to the South Pole for the associated cloud systems to cause some snow. Measured by stakes, the accumulation for a 10-month period was 6 inches in depth. In water equivalent, the average annual precipitation is perhaps 2 to 4 inches.

The characteristics of the snow surface at the pole so far have been only superficially studied, but deserve further investigation. Some practical experiments were performed, mixing snow of different temperatures to form a very hard snow. The construction of a snow compacted runway may be feasible, thereby permitting the landing of wheeled aircraft and greatly facilitating the logistical support of the station and further exploration of the continent.

An extensive radiation, heat balance and micrometeorological program was carried out by Herfried Hoinkes of Austria and Paul Dalrymple of the United States Army Quartermaster Research and Engineering Laboratory, Natick, Mass. Dr. Hoinkes found solar radiation to be as intense at the sea-level location of Little America as at 3,000 to 6,000 feet in the European Alps—a striking testimony to the clarity of the Antarctic atmosphere. At the South Pole he found the snow reflects as much as 94 percent of the incident radiation. Mr. Dalrymple examined the vertical wind profile in the lowest 30 feet and found that in agreement with other determinations the wind speed increased logarithmically above the snow surface during times when the atmosphere was well mixed. He is now carrying out similar measurements at the South Pole Station to see what influences the strong surface temperature inversion and the varying roughness of snow surface have on the vertical wind profile and turbulence characteristics.

There are also continuous observations at Little America of carbon-dioxide concentration, and samples of air are being collected for later analysis for composition, concentration of CO_2, and content of radioactive material. W. B. Moreland, in addition to his duties as Head of the IGY Weather Central at Little America, made hundreds of measurements of the total amount of ozone in the vertical air column, using the sun and the moon as sources of ultraviolet radiation.

Ionospheric physics.—We have learned that there are high electron concentrations and significant diurnal variations in the Antarctic ionosphere during the long winter night. This was unexpected because the ionosphere is thought to be primarily under the control of solar radiation, and would therefore not have exhibited such behavior. The reasons why the ionosphere is sustained during the solar night are still unexplained and a full explanation may appreciably alter our concepts of ionization and recombination in the high atmosphere.

Seismology.—Seismographs located at 5 United States-IGY stations, located a number of earthquakes which would not have otherwise been known. Also, excellent microseismic recordings were taken which will contribute to the correlation studies between meteorology and microseismology.

Gravity.—J. A. Sparkman completed gravity measurements at all of the United States-IGY stations except Ellsworth. During a visit to the Soviet IGY Mirny Station in February 1958 he completed an important gravity tie-in which will contribute greatly to the study of the gravity field of the world. Three hundred and sixty-three precise gravity measurements in 33 days made on the ice shelf at Little America showed a main tidal period of 24 hours, with a maximum amplitude of 5 feet during full and new moon.

Other studies.—Additional important contributions to the program were made on shipboard. Eight ships of Task Force 43 took numerous observations of meteorology, oceanography, ice conditions, bottom topography and obtained bottom cores and marine biological specimens. A rockoon program was carried out aboard the U. S. S. *Glacier* by J. A. Van Allen and L. J. Cahill of the University of Iowa, and cosmic ray, aurora, and magnetic data were obtained between 30° and 72° south latitude.

Although zoology and physiology were not official portions of the IGY program these subjects were by no means neglected. At the Wilkes Station, Scientific

Leader Carl Eklund of the United States Fish and Wildlife Service, banded several hundred skua gulls, branded scores of Weddell seals, surveyed 11 Adelie penguin rookeries on the Windmill Islands, and obtained temperature recordings of incubating penguin and skua eggs.

At Wilkes Station 49 birds representing 11 species, and 1 Ross seal, were collected for the United States National Museum which completes 1 of the world's finest collections for this institution. These were brought back frozen aboard the U. S. S. *Arneb*. In addition, blood samples of the Ross and leopard seals were collected for the United States National Institute of Health for cancer research, and brains of the Adelie penguin and the South Polar skua were obtained for the Walter Reed Army Institute of Research.

Twelve Adelie penguins were taken alive aboard the U. S. S. *Arneb* en route home in February 1958, and these were shipped by air from Sydney, Australia, to the San Diego Zoological Gardens in California. Eleven of these survived the trip and were reported in good condition the following month.

A distribution and life-history study of the South Pole skua was carried out. This involved a cooperative banding program by 7 nations at 18 different stations in the Antarctic. Each station used a different colored band. The total number of skuas banded is not known as yet, but at the United States stations through the 1957–58 nesting season there were reported 31 banded at Little America, 106 at McMurdo Sound, and 107 at Hallett Station. There were 671 banded at Wilkes Station.

At Little America, Fred Milan carried out a physiological program, studying basal metabolic rates, exposure of human subjects to standardized cold stresses, and thermal balance studies. During the summer this study was augmented by personnel attached to the joint British-United States Medical-Physiological Expedition.

This preliminary discussion of the results of the IGY Antarctic program could not have been possible without the assistance of numerous IGY personnel, who not only took the observations under most difficult conditions, but prepared brief monthly summaries for radio broadcast. In describing the meteorological and traverse results, I am particularly indebted to Dr. Wexler and the summaries prepared by Hugh Bennett (Ross Shelf traverse), Charles R. Bentley (Byrd traverse), and Edward Thiel (Ellsworth traverse) for presentation at the IGY Antarctic symposium held in Wellington, New Zealand, in February 1958.

When the full volume of the United States-IGY Antarctic data is coordinated with similar data from other countries in Antarctica many of the pre-IGY scientific secrets of that continent will have been explored. However, there are still many important unsolved problems in Antarctica—not only internal ones but also those relating to the remainder of the planet— and, in recognition of this, the newly established Special Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions (ICSU) has recommended continuation of scientific research in Antarctica after 1958. As Chairman of the United States Antarctic Committee for the IGY, I should like to urgently endorse the SCAR and the National Academy's recently established collaborative Committee on Polar Research for your encouragement and support. These committees are our heirs; their programs, if fully permitted to capitalize on the IGY base which we have laid, will prove most important to our further scientific understanding of the globe on which we live.

PERSONNEL CHANGEOVER IN ANTARCTIC

Dr. WEXLER. The real big event of this last year was the changeover of personnel. We had to bring down a whole new crew of meteorologists, glaciologists, upper air experts, and so on; about 80 people came down and spread out among all of these stations. This changeover was done very successfully, and our new crew is now hard at work. A few of the old crew have stayed over, and Bert Crary, the deputy chief scientist, is resident now for his second year. This is true for 1 or 2 other specialists.

ASSISTANCE OF TASK FORCE 43

Again, I should emphasize the great assistance given to our Antarctic program by Admiral Dufek and Task Force 43. Without them

we would not have started this program in the Antarctic in the first place, nor could we have continued this in the second year with the changeover required. Not only do they help us logistically, but scientifically. Many of the Navy meteorologists helped out to take observations at McMurdo Sound, Ellsworth, and Wilkes.

In the summer season, many programs are going on at the same time, despite the fact that it is a very busy season. Admiral Dufek's Air Squadron 6, under Commander Kelly, ran a regular ferry service for scientists so they could get in and out of areas to carry on their studies, areas never before examined.

SCIENTIFIC PROGRAMS

The programs have been going on, and these, as you know, involve various fields, such as Aurora and Airglow, which will be discussed later.

I would like to indicate that many thousands of man-hours were put into the observations for Aurora during the dark season.

Then we have cosmic-ray measurements, which Dr. Simpson will discuss later. These were taken at the Wilkes and Ellsworth Stations, as well as on board ship. Here again, the task force cooperated in diverting its ships from their regular courses to and from Antarctica in order to accommodate the cosmic-ray-measurements in areas virtually not traveled for many, many years by any ship.

Then we have the field of geomagnetism. Dr. Simpson will discuss this, and all I want to say is that measurements went along fine.

On the traverses, the seismic measurements were extremely useful in getting the ice thicknesses. The gravity measurements also showed the warping down of the earth's crust because of the tremendous weight of ice. Mr. Field has discussed glaciology, and I have already given a good deal of information on meteorology.

On the question of ionospheric physics, we found, to our surprise—Mr. Shapley will develop this more—that there was an upper ionosphere level still present at the pole where sunlight vanished many months before and yet an ionized layer caused by sunlight was still there. Was it a hangover of the former ionized layer, or had it moved in from other portions of the atmosphere? Mr. Shapley will talk about that.

Then we have physiological, zoological, and biological measurements, which were made although not IGY subjects.

BIOLOGICAL WORK

At the Wilkes Station, Scientific Leader Carl Eklund, personally, banded several hundred skua gulls, a sort of scavenger bird of the Antarctic. He put bands around them to find out where they traveled. As you know, skua gulls were observed not too far from the pole and, apparently, they fly across the continent. It has been proved that another form of bird, called the petrol, flies around the continent; that is, from the nesting areas in the Palmer Peninsula. Birds have been banded and observed downwind as you go around the map, way on the other side of the continent in New Zealand and Australia. It is believed that some of these petrols have made the circuit twice. They have not been able to work them into the IGY yet.

This is some interesting information showing that the winds do blow from the west to east and birds do take advantage of that.

TRAVERSE WORK

I would like to elaborate on Mr. Field's remarks on the traverses. We are very proud of our traverses and, altogether, our people have traversed over 5,000 miles since early 1957. These were traverses done not to go from point A to point B, in the quickest time, but deliberate traverses to get the most out of this. Measurements have been made of the ice thicknesses and meteorogical measurements and gravity measurements and geomagnetic measurements and so on.

The Ross ice-shelf traverse and the Byrd traverse party were designated to study the properties of the vast shelf of ice. I was very lucky to be able to join that traverse party and stay 2 days with it as it crossed the 80th parallel.

I joined it in December not far from the spot where Scott died although the weather was a good deal more pleasant than when Scott died in March, by March the weather deteriorated rapidly. The traverse made its way back to Little America by that time, making a vast amount of observations which have now been tested. One unusual thing that was found was that, at the foot of the Liv glacier, the temperature 20 to 30 feet in the snow was about the same as the temperature in Little America, despite the fact that it is 400 or 500 miles to the south.

The reason is that the result is probably due to warm Chinook or Foehn winds blowing down the glaciers from the southeast and the climate is not too much different.

As it is, at Little America, between there, the temperature is about 10° colder than in the South or North. The traverse at Byrd Land has been a very historical traverse and I was on the ham radio with Mr. Bentley, chief seismologist of that traverse, and I can amplify a remark Mr. Field made about 12,000 feet of ice being measured here.

STRUCTURE OF ANTARCTIC CONTINENT

About 14,000 feet of ice were measured resting on bedrock 8,000 feet below sea level. It is probably the deepest and the thickest ice measured anywhere in the world. Two of these three legs of the triangle indicate that the rock is below sea level and the third leg is mostly above sea level. There is an interesting deep trough which the group in the Ellsworth traverse discovered coming in this direction heading toward Byrd, as far as the traverse went. There is some speculation going on that this deep trough is an ocean underneath this layer. It may connect up with this frozen ocean in Marie Byrd Land and actually make a separation of the land portion of the Antarctic between the west Antarctic and a continuation of the mountains here, and east Antarctic between Maud Range in the area of these mountains discovered here.

There is a definite separation. We would not know that until the next season and we made some changes in plans to study that. That goes from Ellsworth to Byrd, and we will have to see if we have means of sounding the ice seismic reflections and if there is underwater connection between Ellsworth and Marie Byrd Land Base.

We have to know about this deep, frozen water here and we really do not know whether this is part of the ocean or whether there is a connection between them, or whether there is an inland sea completely frozen. The traverses are going on next year and I mentioned one of them. We will have another traverse going out from the Pole Plateau from Byrd Station.

Mr. THOMAS. Did I understand you correctly, that you made a sounding and you have 14,000 feet of ice?

Dr. WEXLER. Yes.

Mr. THOMAS. Right there?

Dr. WEXLER. It was resting on bedrock 8,000 feet below sea level.

Mr. THOMAS. Then you do know that the station around Byrd is not a sea? It is based on rock and not water? Maybe I misunderstood you.

Dr. WEXLER. What I think I was trying to say is that there is a sea, but whether it is in an inland sea cutoff with contact from the ocean, we will not know until we map this whole area here. The interesting thing we are trying now to do is to look at this next season and to see whether there is a water connection, liquid water or frozen water, between this area here and this area here [indicating].

Mr. Crary hopes to get on the Victoria Plateau next season. In this area [indicating], which is quite high and where planes have made some preliminary landings, from the area Mr. Field mentioned, I would like to get the tractor up to Shackelton Glacier which is the same glacier Hillary went up in support of a party and made some measurements here.

ANTARCTIC WARMING TREND

As you know, we barely skimmed the cream from the Antarctic. This made a very superficial examination compared to the tremendous problems that are still awaiting us. Almost anything you do in the Antartic yields results because we know so little about it. There is still a tremendous amount of unsolved problems. We do not know how much ice there is. We do know, for example, at Little America since 1912 where Edmundson first established that camp and which has been the headquarters of the Antarctica IGY program, that there has been a warming trend of Little America of about 5° F. since 1912. About half of that warming trend we find at Spitzville. That is tied up with the decrease in pack ice in the Arctic.

Now, for the first time, with the IGY data attached to the earlier data, we scent a warming trend in Little America. We do not know how general this is for the rest of the Antarctic but this trend, should it continue, would not necessarily mean a decrease of the ice because the temperatures are still well below freezing, but it might mean a contradiction to the Arctic. It might mean an increase.

The warmer the temperature grows, the warmer the air control and the heavier the snowstorms are. That might mean a building up of ice here and perhaps a lowering of the sea level over many decades. Since we have only one point here, we really cannot generalize as to the whole Arctic.

FURTHER ANTARCTIC RESEARCH

In recognition of the importance of these problems, the various nations in Antarctica research have gotten together and recommended

further research in the Antarctic after this year. A new committee has been set up called a Special Committee on Antarctic Research, or SCAR, to coordinate the research in the Antarctic, much as the IGY Committee in 1957 and 1958.

ANTARCTIC EFFECTS ON WEATHER

Mr. THOMAS. Let me interrupt you. You say the problem is so big and vast that you really have not had enough contact there to come to any definite conclusions. What connection is there between the area there and your weather problems?

Dr. WEXLER. Well, this may come up in several ways. First, the Antarctic ice and the blowing snow cool off the water here [indicating], and this water, cooling off, sinks below the surface and sort of creeps along the bottom. It has been suspected that this very cold water comes into the Northern Hemisphere and may eventually reach the surface in the Northern Hemisphere. So it may affect the climate by a slow creeping process. It may take hundreds of years to affect sea surface temperatures in the Northern Hemisphere. It could affect the weather through the medium of the atmosphere.

Very intense storms are generated here [indicating]. The number and intensity are probably greater than in any area on earth. These storms affect this area as far as day-to-day weather is concerned. It is very important to the Southern Hemisphere Meteorologic Services to have this service for their daily forecasting for 48 or 72 hours. But for the long period trend it is very likely that the effects and the impulses and the disturbances of the atmosphere these storms create spill over across the Equator into the Northern Hemisphere. We have never been able to test this because we have never had information from the Antarctic that we now have from the IGY.

As I was mentioning earlier, we have never been able to explain the very sudden changes in weather such as the drought last year in west Texas to a condition of flood.

ANTARCTIC WINDS

Mr. THOMAS. You have winds blowing from 150 to 200 miles an hour. With that much atmosphere traveling around at that speed almost anything can happen. What causes the wind?

Dr. WEXLER. The fact is the atmosphere in the interior of Antarctic cools very much. It shrinks vertically. It sort of causes a huge whirlpool to go around this lower portion of the atmosphere. It is a vertical contraction of the atmosphere caused by intense cooling. It sets up a whirlpool. When the sun comes back, this warms up the atmosphere and it expands and, instead of forming a whirlpool like you would see in your bathtub, it is a whirlpool in reverse and the wind goes in the other direction.

Mr. THOMAS. How far does it get away from that area? Does it spill over?

Dr. WEXLER. Not that. It tends to blow this way or that way. Down below the stratosphere, and the layer from sea level up to 30,000 feet, we have a lot of wind that does go back and forth.

Mr. THOMAS. Does the wind in the stratosphere—and I presume you mean above 50,000 feet—encircle the entire globe, or just that portion of the South Pole?

Dr. WEXLER. It will circle the entire hemisphere from west to east, and apparently right over the coast of Antarctica is one of the strongest belts. There are other belts farther to the north at latitude between 30° south and 40° south, but those winds are probably just as fast, but are not at the same height.

UNITED STATES WORK IN OTHER ANTARCTIC AREAS

Mr. JONAS. Why are we restricting all our explorations to one side of the pole?

Dr. WEXLER. You mean in the United States stations?

Mr. JONAS. Yes.

Dr. WEXLER. Each nation, in talking about its plans, designated certain spots they thought they could set up. Historically, we have been in Little America since 1928 or 1929 when Admiral Byrd first set up a station there.

CHOICE OF STATIONS

Mr. JONAS. We are now at Ellsworth. I just wondered why we stayed on that side of the pole and had not been to the other side.

Dr. WEXLER. We have a station down here [indicating].

Mr. JONAS. We have not been doing anything with it, and we have not explored from it, have we?

Dr. WEXLER. We have explored from Ellsworth along this line here [indicating].

Mr. JONAS. I mean the Wilkes Station.

Dr. WEXLER. We have set up a station 50 miles in and we have done certain exploration 100 to 200 miles in the coastal areas, but we never have had the air support. It was never planned to go well into this area. We would like to make a traverse either to the pole or to McMurdo. There is only so much the task force can do. They give us such tremendous support in these other areas.

Mr. JONAS. That is an extensive territory. How far is it from Wilkes to the pole?

Dr. WEXLER. About 1,500 miles.

Mr. JONAS. How can you be sure that you have the same things to contend with down there that you have in the other areas where we are working? Was it an accident, or did we stay on that side of the continent because we started at Little America?

Dr. WEXLER. I think that is it. I think historically Little America has been our base. At McMurdo Sound there is a good place for our heavy planes to land. There is some very thick heavy ice that enables our Globemasters to land. We do not know of any other spot in Antarctica that can accept such heavy planes.

We did make a good many reconnaissance flights in 1955 and 1956 into that area [indicating]. Our people have seen that area, but we have not landed there.

Mr. THOMAS. Thank you, sir.

IGY OCEANOGRAPHY PROGRAM

Dr. KAPLAN. I will now call on Dr. Roger R. Revelle, member, USNC Technical Panel on Oceanography; Chairman of the Special Committee on Oceanography of the International Council of Scien-

tific Unions; and director of the Scripps Institution of Oceanography, University of California.

Mr. THOMAS. It is nice to have you, Doctor. What is your definition of an oceanographer?

Dr. REVELLE. I have given various definitions before this committee.

Mr. THOMAS. Give us a definition now, if you have a new one, or an old one. The last one was some kind of a sailor.

Dr. REVELLE. That is what I said, an oceanographer is a sailor that uses big words.

I have a statement that I would like to file for the record at this point.

Mr. THOMAS. Without objection, it will be inserted in the record at this point.

(The statement follows:)

IGY OCEANOGRAPHY PROGRAM

It is my pleasure to appear before this committee again and tell you of the work in oceanography that has been accomplished in the first 11 months of the IGY. I was able to tell you last year of the early work done before the IGY opened. Since then our programs have been most successful in meeting planned objectives, and this season's work, now underway, includes all elements of the program.

About 25 IGY nations are operating over 350 IGY tide gage stations (some with auxiliary equipment such as long period wave recorders, microbarographs, etc.) in a program to study the monthly variation and the seasonal and yearly mean values of sea level. Over 20 countries are operating research vessels in a coordinated plan to study the circulation and current of the major ocean basins; there are over 80 ships making cruises varying from several hundred to 40,000 or so miles long, from a few days for offshore observations to as long as 10 months for protracted work. The IGY has provided a significant new ingredient to making possible the systematic study of the great ocean systems: international cooperation. One ship cannot learn very much about a great ocean, no one institution or country has 10 or 20 ships to send out in a planned and coordinated cruise; and before the IGY there was not the incentive to attempt such exploration on the scale required to map even one ocean in as much detail as will be obtained during the IGY.

The oceans, which cover about three-quarters of the earth, are a great storage trap for energy; the oceans are responsible for the fact that the climate of lands near seacoasts is more uniform than that of the interior of continents. Great ocean currents such as the Gulf Stream affect climates in the northern parts of the Atlantic Ocean. For example, Iceland and the British Isles have far less severe winters than they would have were the Gulf Stream not flowing.

The surface currents of the oceans are related to the great wind systems, and it has been shown that the Gulf Stream, for example, follows the great clockwise atmospheric circulation in the Atlantic Basin. Benjamin Franklin was one of the first to observe the nature of the Gulf Stream; Lt. M. F. Maury, a leading proponent of the systematic study of the oceans in the mid-19th century, collected much information from mariners bearing on the set and speed of surface currents in this area, but only recently was the Gulf Stream explored in a thorough fashion by several ships in Operation Cabot.

Biologists at the oceanographic institutions take advantage of cruises to collect new specimens. Although properly not part of the IGY program, considerable biological work is accomplished on cruises, and much of it, for example study of plankton, yields information necessary to dating sediment layers, and can contribute to the study of the deep currents.

EARLY OCEANOGRAPHIC STUDIES

In the year before the opening of the IGY, several preliminary cruises were conducted, partially to test new observing techniques, such as the Swallow neutrally bouyant float, and partially to get a head start on the IGY operations. This is possible in oceanography, for in the study of the ocean water masses and deep currents which change only slowly over several years, synoptic observations

need not be strictly simultaneous, as is the case in meterology. Thus by beginning some of the cruise work early, more was accomplished than could have been done entirely within the IGY period.

The deeper currents of the oceans have proved difficult to observe directly, and we have only imperfect information concerning them. It is known that cold water is formed in the polar regions; it is thought that this water, being dense, sinks and flows along the sea floor, displacing water which then flows away from the polar regions toward the equatorial regions. Bottom topography such as ridges, canyons, and mountain ranges influences the flow of bottom waters, and it is possible that some bottom waters become trapped in basins. Above the bottom waters are a series of deep water layers of intermediate density. It is not known whether bottom and deep water makes a circuit from pole to equator and back in tens, hundreds, or thousands of years. The deep waters play an important role in man's economy, for the extent to which the seas can support life is dependent upon the food supply in the water. The deep waters are rich in chemical nutrients, and, wherever these waters upwell, there are found the great fishing banks, such as the Grand Banks off Newfoundland and the Peruvian fishing grounds. Much of the cruise work is designed to obtain information bearing on currents, and several important contributions were made in cruises just prior to the IGY period.

Early IGY work in the Antarctic

In an early IGY cruise, using instrumentation developed only recently by J. C. Swallow of the National Institute of Oceanography in England, the *Atlantis*, a research vessel of the Woods Hole Oceanographic Institution, and the British vessel, *Discovery II*, explored the eastern edge of the Gulf Stream and were able to map for the first time the underlying flow of water. They found that, at depths of about 6,500 feet, there was either very little or very erratic movement; shallower depths showed set to the northeast, as expected, but at depths of about 9,000 feet, the current sets southwest at the relatively high speed of 8 miles per day. This new technique, in which the Swallow neutrally buoyant float is used, enables IGY oceanographers the world over to map both surface and relatively deep currents.

The *Crawford*, also of the Woods Hole Oceanographic Institution, made a 4-month cruise in the Atlantic in 1957. The *Crawford* reoccupied many stations taken years ago by the German ship *Meteor* and discovered that there have been pronounced changes in the amount of oxygen dissolved in the Atlantic in the region of 15° south latitude. The difference in oxygen content over the past 30 years may mean that deep bottom water is not being formed as fast now as it was previously, but further data and analysis are needed for proper interpretation of the present observations.

The research vessel *Vema* of Lamont Geological Observatory completed in August 1957 a 10-month extensive cruise in the South Atlantic Ocean, working along the coasts of South America and Africa and crossing the Atlantic at high southern latitudes between Argentina and Capetown. The *Vema* cooperated with the *Bahia Bianca*, a survey vessel of Argentina, in making explorations of the submarine crust by seismic methods. Considerable marine biological work was also done, and Lamont has reported that living organisms—a small shellfish and a worm one-fourth of an inch long—were recovered alive from depths of 13,200 and 16,200 feet, respectively. Twenty-one deep trawls were made in the Atlantic; previously only 14 such trawls were taken. The *Vema* was equipped with a net finer than was used previously; the use of the new net resulted in an increase of between 5 and 10 over previous work in both species and specimens obtained. Lamont biologists expect that perhaps 100 new species will be discovered in their samples. The analysis and study of samples indicate that the abyssal fauna is geologically new; no samples were found with archaic paleozoic affinities. Over 100 plankton samples were taken and are being studied to determine the natural temperature requirements of pelagic foraminifera as a basis for paleotemperature studies on cores. The South Atlantic samples make possible a comparison of so-called identical North and South Atlantic species and to examine critically the validity of the bipolarity hypothesis.

Early IGY work in the Pacific

In the spring and early summer of 1957, a research vessel of the University of California, Scripps Institution of Oceanography made a cruise north to the Gulf of Alaska. During this cruise an instrument, specially designed to measure continuously the concentration of carbon dioxide in both the atmosphere and sea

water, was tested. This instrument, and three others like it, are now in operation on ships and aircraft of other institutions as part of the CO_2 program.

Early Antarctic oceanography

During Deep Freeze I and II, ships of Task Force 43, with oceanographic personnel from the Hydrographic Office, were able to devote time to collect much oceanographic data, including cores, water samples, biological collections, and surface temperature data.

OCEANOGRAPHIC WORK ACCOMPLISHED IN THE FIRST YEAR OF THE IGY

Atlantic Ocean

Several Atlantic sections were added to the early work done by the *Crawford* of Woods Hole and in addition some very significant work was concluded in the Caribbean. During this work some basins were found where the deep water is isolated from North Atlantic deep water and Carribean deep water, and the characteristics of the isolated water suggest that it is residual from previous ocean circulation patterns under different climatic conditions. These findings are important in relation to the understanding of the circulation fluctuations of the oceans and the relation of such fluctuations to climatic conditions. The work accomplished by the *Crawford* has been of exceptionally high quality, all the more so when it is considered that the *Crawford* is a very small vessel, displacing barely 300 tons fully loaded.

Water samples were collected along 10 sections across the Atlantic for measurement of chlorophyll, and productivity as measured by carbon-14 determinations. These samples represent for the first time adequate information concerning the distribution of organic and inorganic phosphorus in the sea. Woods Hole scientists believe now that productivity in the open sea may be two times greater than previously estimated.

The *Vema* of Lamont Geological Observatory completed the first half of an extended cruise in the South Atlantic. She worked in the western South Atlantic, again in cooperation with Argentine vessels, and then made a section across the South Atlantic to Capetown, penetrating into Antarctic waters as deeply as weather conditions and her strength allowed. Dr. Maurice Ewing, director of Lamont Observatory, was scientific leader during this phase of the expedition which was devoted to seismic and geophysical explorations of the marine crust, collection of water samples for analysis and dating, and precision bathymetry.

Thus far in the Atlantic, the *Vema*, *Atlantis*, and *Crawford* have cruised about 75,000 miles of track taking bathymetric and magnetic recordings, have occupied about 500 deep hydrographic stations, where about 10,000 water samples were taken for analysis in the home laboratories for chlorinity, dissolved oxygen, and other chemical constituents of ocean water, and have obtained over 200 cores in oceanic sediments which will also be analyzed in the home laboratories. In addition, Lamonth has completed over 100 seismic profiles in their study of the marine crust, and has collected over 80 large water samples for tritium and carbon-fourteen determinations. These samples are now being analyzed in the Geochemical Laboratory of Lamont; the information obtained will yield valuable data on ages of water masses and will contribute to the study of oceanic deep currents. Deepwater photographs were also obtained giving valuable information on bottom features and marine life.

Pacific Ocean

In the summer of 1957 the *Brown Bear*, a research vessel of the University of Washington, worked in the Northeast Pacific Ocean where ocean currents were studied. It was found that very high currents exist near the Aleutian passes, where powerful upwelling and mixing processes are evident on the bathythermograph traces to depths of 900 feet. Abrupt decreases in temperature as great as 10° F. appear at the surface. The effect of the currents is easily detected at distance of 3 miles, and subtle effects can be detected even farther away. Along the Shelikof Strait a net flow was found at all depths with an average magnitude of 0.5 knot. A unique feature of the program was the conversion of temperature, salinity, oxygen, and phosphate information to punchcards. This will make it easier to convert the data to the standard depths used by oceanographers and to compute the currents and density gradients.

During the cruise, about 150 hauls were made with a midwater trawl for biological sampling. Several as yet unidentified specimens, possibly new spe-

cies, were collected, but the catch most exciting to the biologists contained two eel larvae about 8.5 inches long. They were still alive and were, with the exception of the eyes, perfectly transparent. It is believed that this was the first catch of these specimens in the area.

Two research vessels of the University of California, Scripps Institution of Oceanography, the *Horizon* and *Baird*, completed a 5-month expedition through the Southeast Pacific. The South American trench along the western edge of the continent was one of the areas explored and charted. Many seismic profiles were run in the areas and along with bottom sediment samples, heat flow measurements were made in many locations and some significant results were obtained. It was found that in regions of uplift of the ocean crust, like the Easter Island Rise (Albatross Plateau), the heat flow was larger than normal, while near regions of severe downwarping of the crust, near the South American Trench for example, the values were much lower than expected. These findings give support to the theory that there exist within the mantle of the earth great convection currents which bring hot material up toward the bottom of the crust in regions of uplift and return this material, which has cooled in the meantime, back down toward the core of the earth in regions of downwarp. In fact, the convection currents themselves may be the cause of the uplifted (plateau) regions and downwarped (trench) regions. These results are indicative of what was learned on this expedition about the marine crust and the sediments deposited thereon.

One finding of possible interest beyond basic research was an area of great extent where the sea floor was partly covered with loose nodules containing rich concentrations of manganese, copper, cobalt, and nickel. It is interesting to speculate on the possibility of "mining" the ocean bottom for strategic materials.

During the cruise a carbon dioxide analyzer was operated continuously to measure the concentration of carbon dioxide in the air. This work is part of a general program to assay the content of carbon dioxide in the atmosphere and to study the equilibrium and exchange mechanisms of carbon dioxide between air and ocean water.

In the Pacific, the *Brown Bear*, *Horizon*, and *Baird* have cruised almost 50,000 miles, have occupied over 300 hydrographic stations where about 5,000 water samples were obtained, took over 200 cores, secured 28 large volume water samples for carbon-14 determinations, took 25 deepwater photographs, completed 39 seismic profiles, and made 39 heat flow measurements in the marine crust of which 32 were completely successful. This latter statistic is important as heat flow measurements through the crust are vital in understanding crustal structure, and up until this time only about 25 such measurements had been obtained.

Island observatory program

Another part of the IGY oceanography program is the study of the mean sea level over the period of the IGY. It has been found from study of tide data that there seems to be an exchange of water between the Northern and Southern Hemispheres as the seasons change. Some of the change in mean sea level between summer and winter has to do with the expansion and contraction of water with temperature. Many new tide gages have been set up to supplement the existing network including: Bermuda, Iceland, and the Azores in the Atlantic; and the Caroline, Line, Phoenix, Galapagos, and Marshall Islands, and at islands in the Southeast Pacific Stations at locations under the jurisdiction of other countries were established in cooperation with scientists of those countries. A station is in operation on Pitcairn Island under the supervision of a descendant of one of the mutineers of H. M. S. *Bounty*.

Polar oceanography

In the Arctic Basin, United States oceanographers pursue their science from camps on the frozen ocean. The track of one of the stations has carried observers over what appears to be a newly discovered ridge, or underwater mountain chain. Scientists of the Soviet Union are doing similar work at two stations in the Arctic Basin.

At both stations Alpha and Bravo in the Arctic Basin, productivity of Arctic waters is being studied in detail, including phosphorous determination, measurement of photosynthesis, study of the standard crop of plants, and research on water chemistry, hydrography and solar radiation in the manner in which they influence the biological environment. Woods Hole scientists have collected crustaceans which have not been previously reported in that point of the Arctic.

In the Antarctic the ships of the various nations supporting scientific stations

on the continent engage in oceanographic observations en route to and from the area. Thus, U. S. S. R. and New Zealand ships have added to our knowledge of these waters. Ships of the United States Navy Task Force 43 are also exploring the coast, charting the bottom, and taking bottom and water samples for future study.

OCEANOGRAPHIC WORK IN THE REMAINDER OF THE IGY

Atlantic ocean

The *Atlantis* of Woods Hole left late in April of this year for the Indian Ocean, via the Mediterranean and Red Seas. She will meet the *Vema* of Lamont Geological Observatory in the Indian Ocean. The two ships will conduct seismic operations there to study the crust under the oceans. The *Atlantis* will conduct standard oceanographic observations and the *Vema* will take large volume deep water samples, sediment cores and measure CO_2 concentrations in the air and surface ocean water. The two ships will then make traverses across the Red Sea, which has never been studied in this manner before. The crust under the Red Sea is thought to be a gigantic rift, and there has been observed deep water in the Red Sea with very high salinity. In July the ships will work in the Mediterranean Sea, and return in August through the Atlantic Ocean, where they will occupy traverse sectons as part of the international plan to cover the Atlantic Ocean.

The Agricultural and Mechanical College of Texas has recently acquired a new research vessel, the *Hidalgo*, a converted yard minesweeper. The *Hidalgo* has been fitted out with a scientific laboratory and oceanographic winches. She is now making a 2-month cruise through the Caribbean and western central Atlantic Ocean. The Department of Oceanography at Texas A. & M. College has also instituted an important geochemical program and has made arrangements with Argentine and United States Navy vessels traveling to the Antarctic to collect large water samples for chemical and radioactive isotope analysis for dating water masses.

Pacific ocean

In 1958 the *Brown Bear* will make a similar cruise to that of 1957 and occupy many stations occupied some 30 years ago by the *Carnegie*, a nonmagnetic research vessel operated by the Carnegie Institution of Washington, which burned after an explosion in 1929. The *Carnegie* made significant contributions to marine sciences and to knowledge of the earth's magnetic field. The comparison with present day data with that obtained earlier by the *Carnegie* will be most important in studying the epochal changes in the oceans.

The Scripps vessel *Horizon* and the *Hugh M. Smith*, Fish and Wildlife Service, are now completing the second University of California IGY cruise studying newly discovered currents in the equatorial region. These currents flow from west to east at depths between 200 and 1,000 feet and are one of the most important current systems known. A third IGY expedition, again in equatorial waters, will take place in August, when a Colombian frigate will join the *Horizon* and *Baird*. In this cruise, currents flowing counter to the equatorial countercurrent will be studied and mapped.

LONG-TERM OCEANOGRAPHIC PLANS

The IGY has already made a profound impact on the science of oceanography. The work accomplished in 1957–58 will stand as a landmark for a long time in the history of our science. There are too few oceanographers and too few ships to do all that we want to do, and oceanography is a very expensive and time-consuming subject. The IGY provided, as I mentioned earlier, a most essential ingredient to maximize the work that could be done with existing scientific resources. The international cooperation which is an integral part of the IGY has made an impact on oceanographers perhaps more profound and of more lasting importance than the IGY program itself. So stimulated by the early success of the kind of cooperation fostered by the IGY and over prospects of continuing cooperation and international planning were oceanographers, that a Special Committee on Oceanographic Research (SCOR) was organized by the International Council of Scientific Unions (ICSU). Several meetings of SCOR have already been held. We are planning for example, a long program of stimulating oceanographic research in the Indian Ocean and of encouraging and training scientific talent in the countries bordering that area, and similar work elsewhere. The National Academy of Sciences has also recognized the need for long-range planning and has organized a new Committee on Oceanography, under the chairmanship of Dr. Harrison Brown, California Institute of Tech-

nology. The Academy's committee has several panels to study specific questions such as design of oceanographic research vessels, new devices to explore the oceans, and marine resources. The Academy's committee will be this country's liaison with SCOR.

The planning of both SCOR and the Academy's committee carries far beyond the specialized IGY program in oceanography. Included are marine biological studies with emphasis on fisheries and food production in the sea, and concerted attacks on little studied regions, such as the Indian Ocean program I mentioned.

Before the IGY, oceanographers were content to work by themselves, only occasionally coordinating activities with other institutions at home or abroad. The IGY has changed this, in a way undreamed of only a few years ago. The same number of ships and oceanographers are now doing work impossible before the IGY, with the additional of an intangible but essential element: international planning and coordination.

Dr. REVELLE. I thought that today I might be a little more scientific.

DEFINITION OF OCEANOGRAPHY

Oceanography is essentially the study of that part of the earth that is covered by water, which is about 71 percent of the total surface of the earth. It is not really a science at all, and in that it differs in some respects from some of the other areas that are being covered today. It is the application of many different sciences to studying this very large part of the earth. It especially involves the use of ships.

More recently we have been interested in other ways also of studying the ocean. You might say any kind of science you do on a ship could be regarded as oceanography, in a broad sense.

MARINE GEOLOGY

The oceanographers are concerned with a variety of problems, and for that reason they have received support from various parts of the IGY program. We are concerned with the earth under the sea, that is, the rocks and the sediments of the sea floor. The reason that they are interested in this is because they are interested in the history of the earth. This you might call submarine geology. The whole problem of geology is to find out what happens to the earth. It is quite obvious you cannot find out very much about it until you find out what happens under the ocean, because the ocean covers so much of the earth's surface.

WAVES AND CURRENTS IN OCEANS

Second, the oceanographers are concerned with the properties and the oceans of the ocean waters. In the ocean there are the wavelike motions that everybody can see on the surface. The sea surface is never still. We can always see it moving. These are mostly wave motions, and then there are the motions that we cannot see, the currents.

Unlike the atmosphere, where the winds are variable, where the winds blow, the characteristics of the motions in the ocean, the currents in the ocean, are that they are like rivers. There are places where the water is moving fast, or relatively fast, and other places where the water does not move much at all.

There are two kinds of rivers in the ocean, the rivers that we have observed near the surface like the Gulf Stream and the currents in the equatorial regions. These are fairly well known. Something has been known about them for several hundred years.

The second currents are the currents below the surface which we are just finding out about now, but about which we do not know much. Apparently in some places they are very strong and as large as the surface currents. That is one of the remarkable discoveries of the last few years, particularly of the IGY.

MARINE LIFE

Oceanographers are also concerned about the living creatures in the seas. We can think in this respect of the whole ocean as a living organism, as a living cell, with the individual organism as a sort of nuclei, or centers of action in this great living cell of ocean. The organism leaks materials into the water, particularly substances which are present in quite small concentrations, and these determine the existence of other organisms. So, as far as the plants and the animals of the sea are concerned, they really affect each other more than the ocean affects them.

PROBLEMS OF SHALLOW WATERS

Oceanographers also are concerned with processes along shore lines having shallow waters. You, as a Texan, are very aware of many of these problems which have arisen in connection with offshore drilling for oil—the problems of the waves, the big waves resulting from the hurricanes which are very destructive to the Texas towers, the problems of laying pipelines in shallow water, the problems of erosion of shorelines and changes in the shorelines.

RELATION OF OCEAN AND ATMOSPHERE

Finally, the oceanographers are concerned with the interaction between the sea and the air. Here they work very closely with, and are really the same kind of scientists as, the meteorologists. The ocean and the atmosphere together are to be thought of simply as a great steam engine with a boiler in the tropics and the condensers in the polar regions.

There are really two steam engines, that of the atmosphere and the ocean. But the working fluid is not only air but also water, and water in the form of vapor in the air, which comes from the ocean.

In this combined steam engine the ocean is the conservative member of the team. It tends to slow things down and stabilize things. It acts as a reservoir of heat and an absorber of carbon dioxide. One simple figure that emphasizes the nature of this interaction is the fact that about a third of all of the energy of sunlight that reaches the earth's surface goes into the evaporation of sea water, sea water going from the sea into the air, and it all then has to come back.

Now, what needs to be done to find out more about the ocean? There are really two things.

First, to make surveys, and second, to ask questions, to do scientific research.

NEED FOR MORE SURVEY WORK

Two kinds of surveys can be made now and need to be made. One is surveys of the deep sea floor. We know quite a bit about the shallow water areas, the depths and the topography, the shape of the shallow water areas around the borders of the continents, but we have very little knowledge of the topography of the deep sea. Only about 2 percent of the deep sea floor has been even moderately accurately surveyed. As far as our understanding of the topography of the sea floor is concerned, we are now about where we were a hundred years ago in surveying the land—about where we were in 1850 or 1900.

Just as an example of how little we know, from the recent IGY expedition to the southeast Pacific, the Downwind Expedition, a great underwater mountain range was found 1,000 miles long and 200 miles wide. Just imagine a discovery of a major feature of the earth's surface in the year 1958 as big as that—a major mountain range.

One might very well ask why should one make these surveys, and I think the obvious answer is that we are getting to the point where we are actually exploring the ocean bottom and operating in very deep water.

The French, for example, have sent manned vessels down to about 1,500 feet. We can expect within the next 20 years that there will be many vessels operating in these very great depths. It is certainly important to know what kind of bottom they are operating over.

NEW TECHNIQUES

Mr. THOMAS. What kind of vessel is that?

Dr. REVELLE. In this case a thing called a bathyscape, a heavy sphere with a balloon on top. We are at a point now where we have to use balloons. This balloon is filled with kerosene rather than hydrogren or helium. It is a balloon that goes down and drops ballast and comes back up. The bathyscape is coming to this country and will be operated by the Navy Electronics Laboratory starting this summer. One reason why such surveys of the deep sea floor have not been made before is that we did not know how to make them. It has only been within the last few years that techniques have been developed which make it possible to make rapid and accurate surveys.

IMPROVED NAVIGATION, BATHYMETRY, AND OTHER TECHNIQUES

Tests and techniques consist of better navigation. When you are at sea generally you are always lost, and it has been only within the last few years that fairly accurate and reliable navigational methods have been developed.

Mr. THOMAS. What is the temperature of the water at 1,500 feet?

Dr. REVELLE. A little above freezing, about 34° F.

We also have methods of making soundings continuously, and we can sound in any depth with an accuracy of about 6 feet.

We can also survey other properties of the sea bottom. It is becoming possible to measure the force of gravity all over the ocean from a surface ship. It is possible also to make magnetic maps of the sea floor, again on a surveying basis.

A great deal of work needs to be done simply in surveying by standard or well-developed or fairly well developed methods. It has

been estimated that in order to do this it would take about 300 ship-years; 1 ship operating 300 years, or 300 ships operating for 1 year, or 30 ships operating for 10 years.

Mr. THOMAS. It is obvious that that will be a source of much information. Do you suspect those vast depths will influence weather in any way?

SURVEY OF WATERS OF THE OCEANS

Dr. REVELLE. Well, I would think so. If I may, I will come to that in a minute. What we are concerned with in such problems as weather and climate are surveys of the water rather than the bottom. Here we are concerned with measuring the surface, finding out how broad and how narrow, how deep and how fast the surface and subsurface currents move, and particularly how they vary. They are by no means constant. They vary in position. They wander. These rivers in the sea do not stay put in their beds, but they wander over quite wide areas. They seem to flow here and not flow here. We find streaks of fast-moving water and nobody seems to quite understand how this zone of fast-moving water starts.

These currents at the surface are driven by the wind. With regard to the subsurface currents, as I said before, we are just beginning to know how to measure them, and among the first measurements are those made by the IGY.

NEW DISCOVERIES OF OCEAN CURRENTS

Two of the most striking results of the discoveries are, first, a current under the Gulf Stream off the east coast of the United States, which flows at a speed of about 8 miles a day and carries just about as much water as the Gulf Stream itself, and second, another current which was discovered only 3 or 4 years ago and is now being measured during the IGY, and it is a current that flows right along the Equator.

We have known for many years that at the surface along the Equator there was a current that flowed from east to west, from Panama toward Asia. We are now finding that a depth of between 200 and 1,000 feet there is a current which flows in exactly the opposite direction from Asia toward Panama, which we call the equatorial undercurrent, and this current is a huge affair. It carries about 1 billion cubic feet per second, about 1,000 times the transport of the Mississippi River.

Just think of a river in the ocean of this size, and its very existence was not known 3 or 4 years ago.

One of the reasons that we are able to study these currents now and have not been able to do much about them before is we are now able to make land out of the ocean; we are able to plant buoys in water of 15,000 to 20,000 feet and have them stay put and stay in one place months on end.

Meteorologists have always been able to have a fixed point on land and follow a balloon up to study the wind and the upper air, but to try to do the same thing from a ship is impossible because the ship moves all the time and you really do not know where it is moving. So it is only because we have been able to make land out of the ocean that we have been able to really get at these deep currents. We are using exactly the same techniques that the meteorologists have

used for a long time. We send balloons down below the surface and follow their movements, essentially pilot balloons.

STUDIES OF OCEAN CROPS

Another type of survey that needs to be made is the study of expanding crop of organisms—how many plants and animals there are in the sea.

Secondly, and perhaps more important, how fast do they grow? The technical word for it is the productivity of the sea. How much can you grow per acre?

There is a great deal of argument about this. Some people say that there is a lot less production per acre in the ocean than there is on good Iowa farmland. Other people say that there are many areas in the ocean just about as fertile and productive as the best farms on land. The question of production and the amount of growth in the sea is really basic to any long-range thinking about how much food we can supply from the ocean for our very rapidly growing population.

CHANGES IN PRODUCTIVITY WHEN TEMPERATURE OF OCEAN CHANGES

We are also concerned with the variations and conditions. A wonderful example of this is what has happened on the California coast, or off of California, during the past year. Ten or twenty years ago one of the major industries of California was the sardine fisheries. It was the largest fishery in the United States, something like 500,000 tons of sardines were caught a year. Then just after the war, the sardine crop went down and down and down until 1951 only about 3,000 tons of sardines were caught. There were a lot of explanations. Everybody had an explanation for it. Many people said that it was due to overfishing—that the sardine fishermen caught too many sardines. One of the curious things was the temperature during that period of the declining sardine crop of the waters was lower than it had been during the years of the big catches.

Just during the past year the temperatures warmed again all along the coast and out to sea for 200 or 300 miles. We had temperatures which are 2° to 4° F. warmer than they had been during the past 10 years, and the surprising thing is the sardines are spawning off of California and Monterey.

We know very little about it, but we believe it is also possible that there are small changes in the temperature of the deep water. These changes in the temperature of the deep water must have a profound effect on climate. A tremendous amount of solar energy is required to bring about a very small change in temperature in deep water.

OCEANS AS A RESERVOIR OF HEAT

Dr. Wexler talked about the amount of ice in the Antarctic. We can get some feeling for the enormous conservative nature of the deep water when I point out that it would take about 2½ years of sunlight, all the sunlight falling on the earth for 2½ years, to melt the Antarctic ice. This same tremendous quantity of sunlight would change the temperature of the deep water of the ocean by only about a degree, so the ocean is a great reservoir of heat.

Mr. THOMAS. Just 1°?

Dr. REVELLE. That is right. A very slight change in the temperature of the deep water would mean a great absorption of the sunlight.

Now, at the same time that the waters off California warmed up, the waters off of Peru also warmed up. There was again some kind of a shift in the circulation pattern so that the offshore waters moved in close to the Peruvian coast and the tuna fishermen found their fish much farther south than they used to find them. There were mass mortalities of fish, anchovies, and other fish, right off the Peruvian coast. A great many things happened. It was a sort of catastrophic event, and in the Hawaiian area there was the first hurricane. Conditions were quite different off of Japan. There was an actual oceanwide phenomenon. It may be that something happened like this—the wind slackened in some way and the warm waters in the center of the ocean slopped over to the edges and we had a warming all around the edges.

OCEAN TEMPERATURE AND CLIMATE

You asked me about the effects of the deep part of the ocean on climate. Many meteorologists and oceanographers believe there is a very intimate relationship of what happens in the ocean and what happens to the atmosphere over long periods—changes that we call climatic changes, changes that take place over 10 years or more or perhaps 50 years.

I have said this on many occasions, but I think it is well worth putting it in the record again, that climatic changes over decades, over a period from 10 to 100 years, are perhaps the most important geophysical problems there are from a practical viewpoint. These would affect strategy, affect farming, affect the planning, and the development of nations.

For example, the climatic changes that have taken place in the Soviet Arctic have really greatly strengthened the Soviet power. At the same time, take our California situation. A slight shift of the isotherms and the lines of equal temperature and the lines of equal rainfall—a shift of only about 100 miles—would make southern California, instead of being practically impossible to live in as it is now, quite impossible. This would affect literally 10 million people, a very large part of the people of the United States.

I think there is no geophysical problem more important than climatic changes. I do not think that Dr. Wexler would deny the statement the meterologists at the present time have no idea whatever how to forecast it, or what to do about it. That is really the ultimate justification of a great deal of this work in the ocean and in the atmosphere.

DISPOSAL OF RADIOACTIVE WASTES

Another very important aspect of the work on deep water is in connection with the peaceful development of atomic energy. You get widely different opinions about this, but one thing is certain: The peaceful development of nuclear fission energy will produce an amount of radioactivity per year equal to the explosion of about 10,000 megaton weapons, about 10,000 megaton fission bombs. Something must be done with this very large amount of radioactivity.

The Atomic Energy Commission and many engineers in this country are convinced that we can put it in holes in the ground—mostly in Texas, I believe. I think this is likely to be difficult in countries like England, Japan, and Italy who have small populations and small land areas and very few holes in the ground.

These countries, which also have very long seacoasts, and easy access to the deep sea, are very likely to deposit large quantities of their radioactive waste in the deep sea.

Mr. THOMAS. What will that do to the marine life?

Dr. REVELLE. That is a very good question, and we really ought to find out before we start doing something about it.

Mr. THOMAS. I think so myself. If the sea is as productive as our land, which you say could be true, we do not want to cut off that very huge source of food.

Dr. REVELLE. I think that a great deal could be done in the deep sea without affecting our marine harvest, but that is just a guess on my part and really we ought to find out.

VALUE OF INTERNATIONAL COOPERATION

So far, I have been talking about the surface. Actually, these studies can be conducted by a standard but newly developed engineering techniques. That will require a great deal of effort for the studies of the water, some 700 ship-years are required, that is, 70 ships operating for 10 years. If we add that to the studies of the bottom, we need 100 ships operating for 10 years. At the end of the 10 years you will have to start all over again on most of this work.

That is too large an area for the United States. The United States cannot take the responsibility for the whole ocean. We ought to share our proportionate part. Perhaps the United States could do 30 percent of it, which would be 30 survey ships.

This means also that we ought to encourage by every possible means international cooperation in making such surveys and encouraging the Japanese and the Russians and the British and the French and the Germans and the South American countries to play their parts.

REQUIREMENTS FOR BASIC RESEARCH

The second thing we need to do with regard to the ocean is to be able to answer questions about it as opposed to making these surveys. We need to do some fundamental research.

Among some of the questions that need to be answered are: what drives the ocean currents? What makes the ocean currents move? We think that the currents at the surface are largely driven by wind, but we really have no idea what drives the currents beneath the surface.

Secondly, and perhaps even more fundamental, how is the ocean stirred or mixed? We think in general that the surface waters slop around just like the water in a bathtub, under the action of the wind, but then beneath the surface the ocean is stratified and the layers are quite thin. You can think of these layers slipping over each other like cards in a deck of cards, and it is difficult to understand how mixing takes place from one card to the next.

PROBLEMS CONCERNING PRODUCTIVITY

We need to know about the efficiency of marine organisms. On land we know it takes about 1 ton of grass to produce 2 pounds of cow and about 200 pounds of cow to produce 20 pounds of man. In the ocean, it looks as if marine organisms are much more efficient. If they were not, it is hard to see how they live at all.

We think it is possible that 1 ton of diatoms produces 500 to 1,000 pounds of plankton. These are tiny little animals that live on the plants of the sea. Perhaps at each level of the food chain in the sea the marine organisms are more efficient.

THE OCEAN FLOOR

We need to know what the rocks are like under the sea. One simple question that you might ask is, Why is not the ocean floor like the surface of the moon? Why does it not have a series of craters in it like the moon? We know enough about it to know that it does not. It has a lot of other remarkable features. One of the most outstanding in characteristics is the fact that the very deepest water in the ocean is quite close to the continents and right close to the islands chains in a series of long, straight, or nearly straight deep gashes in the sea floor.

MARINE TRENCHES

For example, I have a chart here of the area of South America. This is the result of our recent IGY expedition to the southeast Pacific. Here we have the greatest difference in elevation on earth, from some 25,000 feet beneath sea level right off the shore to the top of the Andes 100 miles away, some 23,000 feet above the sea level.

So you have here nearly 50,000 feet of difference in elevation.

Mr. THOMAS. Is that a general pattern?

Dr. REVELLE. That is a general pattern of the Pacific; not in the Atlantic.

Mr. THOMAS. What is the curve right in the middle of the map? What does that indicate?

Dr. REVELLE. That is the track. Then there is another line that you cannot see, the dashed line, which is the other ship. Two ships took part in this expedition. The information obtained, plus previous information, has been used to make this chart.

Mr. THOMAS. What causes the variation?

Dr. REVELLE. That is the question. That is one of the questions we have to ask about the ocean.

In the western Pacific you find trenches and instead of them being 25,000 deep, they are 30,000 feet deep off the Philippine Islands and off of Guam.

Mr. THOMAS. You have the deepest troughs close to the land areas?

Dr. REVELLE. That is right. There has been a great deal of interest in these great trenches of the western Pacific in the last few years. One of the most remarkable things about them is that the four deepest trenches are within 600 feet of the same depth—within 600 feet of 35,000 feet. It looks as though there must be some reason for this: that this is the deepest hole that you can dig in the ground, that you cannot go over 35,000 feet without the sides caving in. In any case, it is a fact.

We do not know why. They are almost identical in depth, these deep ones, so when you read about the Russians, the British, and the United States making the deepest sounding in the oceans, it always within a few feet, more or less.

FRACTURE ZONES

We have a great many other characteristics of the deep-sea floor. We find very long and straight fracture zones, ridges and long narrow troughs in echelons, or parallel to each other. These zones are 50 to 100 miles wide and extend for thousands of miles in a straight line right across the ocean.

CONTINENTAL SLOPE

We find perhaps the most remarkable feature of all is the continental slope.

The characteristic thing about the earth's surface is that we have two average elevations, or main elevations; (i) continents themselves, and (ii) the deep sea floor. The continents rise about 2,500 feet above sea level on the average, and the oceans extend down 15,000 below sea level on the average, and between these main depths there is a rather sharp drop which is called a continental slope, all along the edges of the continents.

This raises a fundamental question, why should there be oceans at all? Why should not the oceans just cover the earth in a thin sheet of water rather than being confined to these ocean basins? We can ask the further question, why should there be an ocean at all in the sense that we have so much water on the earth's surface.

Other planets in our solar system, for example, Mars, do not have any water to speak of on their surface, and we have this very large amount of water which is confined in the ocean basins.

PROBLEMS OF TIDES

Another question that could be asked about the ocean is, What are the tides like in the open sea? We have a pretty good idea of what the tides are like near shore, but we do not know at all how the water rises and falls from shore. There are some very peculiar tides that we are just finding out about. Actually, it is partly as the result of the IGY.

One of them is the 14-month tide. Everybody is familiar with the 12-hour tides and the 24-hour tides. We know that the water is higher every 2 weeks than it is in between times. The mathematicians have shown that there is an annual tide and that there is even an 18-year tide.

One thing that came out of right hard thinking by Professor Waterman was that there ought also to be a tide for a 14-month period, and the reason for this is that the earth wobbles, or shifts on its axis by about 30 feet in a 14-month cycle, and this ought also to shift the water all over the ocean by an amount somewhere between a third and a half of an inch. They found this out in just the last few weeks.

CHANGES IN SEA LEVEL

We can ask in more general terms, What causes changes in the sea level, and what causes changes, that are about 1 foot, between summer

and winter, between fall and spring, in the sea level? We think this is largely due to the warming and cooling of the water, but it may also be due to the movement of the water, perhaps between the Northern and the Southern Hemispheres.

CHANGES IN CLIMATE AND CARBON DIOXIDE

Finally, coming back to the climatic problem, we can ask, How does the interaction between the oceans and the atmosphere affect the climate? As I told you in our previous session, we are now conducting a great experiment to find out something about climate. More or less, in spite of ourselves, we are adding carbon dioxide to the atmosphere in large quantities, so much so that by the year 2000 we will have added about 70 percent of the carbon dioxide in the atmosphere. We will nearly double the amount of carbon dioxide in the atmosphere. Most of this carbon dioxide will probably go into the ocean because the ocean is a great absorber of carbion dioxide. The question is, How much will go into the ocean and how rapidly will it go into the ocean, and how much will it increase the CO_2 content of the air and increase the greenhouse effect, the absorption and the back-scattering of infrared radiation, which is perhaps the basic controlling factor of the temperature of the atmosphere?

The characteristic thing about climatic changes in that we have what the electronics engineers call the feedback effects.

For example, supposing we slightly increased the temperature of the air. Then we increase the evaporation from the sea surface and increase the water vapor content of the air, which in turn increases the greenhouse effect, which warms the temperature still more, and you just go on indefinitely, building up the temperature. Or you do various other things, like, for example, warming the sea surface. That in turn changes the stratification pattern, changes the absorption of heat in the deeper layers.

So the subject is extremely complicated and extremely hard to work out mathematically because of these self-generating or self-accelerating effects—the so-called feedback effects.

ADVANCE IGY PLANNING

Coming specifically to the IGY program in oceanography, there are two things that can be said that have been the heart of the oceanographic problem of the IGY. One was there was a good deal of planning in advance for surface operations.

The Russians took the middle part of the Pacific Ocean, for example, and the Americans took the eastern side and the Japanese took the northwestern side, and secondly, for the first time we have a rapid exchange of information to the data centers.

RECENT DISCOVERIES IN THE PACIFIC

As to the examples of results, I might specifically talk about what the Scripps Institution's *Downwind* expeditions in the southeast Pacific have done because I know more about that than some of the other work of the IGY.

One of the principal objectives of this program was to study the deep and bottom waters and to find out what is affecting their

movement and their temperature. More or less incidental to this, we have made what might be a most profound discovery. We measured the heat flow in the interior of the earth which warms the deep water of the ocean

MEASUREMENTS OF HEAT FLOW

Previously we had made altogether, in both the Pacific and the Atlantic Oceans, about 25 such measurements of the heat flow from the interior of the earth. On this one expedition to the southeast Pacific we made somewhere between 32 and 38 such measurements. We found a most remarkable pattern of these measurements of the heat flowing from the interior of the earth.

There is a great ridge, or high area, right down the middle of the east Pacific called the Albatross Plateau. Along a narrow zone right down the spine of this plateau, there is this high area. The heat flowing from the interior of the earth was something of the order of 300 calories per square centimeter per year.

This very high value was in a narrow zone some 3,500 to 4,000 miles long and about 200 miles wide right down the spine of the Albatross Plateau. On the other hand, in the trench of that area that I was showing you just off the South American Continent, the average values near the trench were on the order of 10 calories per square centimeter—very, very low values; one-thirtieth of the value.

Mr. THOMAS. What is the difference in depth there?

Dr. REVELLE. There is a big difference in depth. In this narrow deep area we find very low values of the heat flow. In the shallow area we find very high values.

Mr. THOMAS. One is 25,000 feet deep and the other is what?

Dr. REVELLE. The other is about 9,000 feet deep.

RELATION OF HEAT FLOW AND TOPOGRAPHY

Mr. THOMAS. Is there any connection?

Dr. REVELLE. That is what we think. We think that this is a growing ridge; that this is an area where the earth is very active, where things are happening beneath the surface of the earth, pushing up this great ridge. In fact, what we think is that there may be an upward movement of rock—a very slow movement of rock upward from the bowels of the earth under the ridge and a downward movement under the trench—the trench is actually being pulled or sucked down by the downward movement and the ridge is being pushed up by the upward movement.

On the other side this mountain range that I was telling you about, which we found coming out from the coast of South America, we found that the normal value of the heatflow is about 40 calories per square centimeter. We found fossils on the summits of the mountain range—shallow fossils—which indicate this mountain range is a very old thing. It has been there and it is not changing much except by going down beneath the surface. It must have been once at the sea surface about 20 million or 30 million years ago; since then it has gone down about 4,000 feet. The top of it has gone down about 4,000 feet beneath the sea surface. The studies of the trench indicate that it is probably being formed today and the evidence for this is that there is no

sediment at the bottom. It is V-shaped and goes down to a rocky, deep fiord just as if there were a continuous folding down like this [indicating] beneath the surface.

MEASUREMENTS OF CARBON DIOXIDE

The measurement of carbon dioxide content of the air and water, which is being coordinated on a worldwide basis, has shown that there is very little variation from place to place in the area. Once you get away from cities and trees and once you get away from the effects of the land, all of the way from the Aleutian Islands, 50° south latitude, the variation in the carbon dioxide content was less than 1 percent than the total CO_2. The total of CO_2 is not very great. It is only about 3 parts per 10,000 although it has a profound effect on the atmosphere.

DEEP WATERS

We have gotten quite a bit of information about the deep waters in terms of how long it stays down and where it comes from. This is also being attacked by using carbon 14 and radioactive isotopes of carbon.

It is also being attacked by studying the various decaying processes of the uranium and thorium series. These show that the deep waters in the Western Pacific and the deep waters in the Eastern Pacific apparently come from different places and there is quite a difference in the source of this water and where it has traveled.

MINERAL DEPOSITS

Perhaps one of the most interesting potentially practical results of the expedition was the finding that literally millions of square miles in the Southeast Pacific contain loose nodules of manganese and iron and have up to 1 percent of cobalt mixed with copper. The values in terms of these metals are something of the order of $500,000 per square mile. We have recently asked the people at the College of Mining at Berkeley to assay how much it might cost to get these things up. They think, in fact, it might be quite possible to get it up and process it at a cost relatively small compared to the metallic values that exist there. This is particularly interesting, of course, because cobalt and nickel are metals that are not very abundant in the United States.

Mr. THOMAS. Doctor, may I interrupt? We do not want you to stop but we want you to take on a little nourishment so you can pick up where you left off. We are not going to let you stop anytime soon.

(Recess.)

Mr THOMAS. The committee will please come to order. Before adjourning, we were listening to a very interesting and able statement by Dr. Revelle. Will you continue, please.

Dr. REVELLE. I just have a few minutes more. I should like to make some general remarks about the IGY oceanographic program, about the future.

IMPACT OF IGY PROGRAM

I think you can say three things about the IGY program as it has affected the studies of the ocean. First, through the funds made available by the United States Congress and because of the international planning, we have been able to explore parts of the ocean that have

never really been looked at before, which includes the South Pacific which was very little known and the Indian Ocean which was even less known. In more general terms, we have been able to study the deep part of the ocean as opposed to the coastal areas, which are the principal areas that have been studied by the fisheries people.

I told you about some of the results of the expedition to the southeast Pacific where we found every day something new. It was like exploring a new world.

INTERNATIONAL PLANNING

The second general impact that the IGY program has had has been that we have learned a lot about international planning. Oceanography is somewhat different from meteorology in that you do not have to have day-to-day communication. Since the IGY began we have had very little contact with the oceanographers of other countries except to receive reports of what they are doing, but they are all working on the plans for dividing up the exploring job that we worked out before the IGY began.

So that we really did two things. We worked on a program. We asked, in other words, what questions did we want to have answered. Secondly, we planned ship operations and island operations that would at least begin to give answers to these questions. Third, we had some exchange of people between countries particularly with the British in our case and with the Japanese, not so far with the Russians although we have talked about it. So far we have not been able to carry it off.

STIMULATION OF OTHER COUNTRIES

The third thing that has happened has been that many smaller countries have undertaken an oceanographic program, and some of them quite effectively, who were not very heavily involved before. In South America, for example, the Brazilians are doing quite a bit between their coast and Trinidad. The Argentines have done a great deal, and have worked in close cooperation with the Lamont Observatory at Columbia University. The Chileans have done more than they have done before. They have sent people to our place to learn. They have operated on Easter Island and Juan Fernandez Island and with ships. We have the Colombians about to cooperate. In Thailand, the Thai Navy, which is a very nice navy and has not much to do except something like this, has found a mission in life, namely, doing oceanography in the Gulf of Thailand.

The special things the IGY has brought in have been exploration of parts of the ocean never really looked at before, experience in international planning, asking questions and planning ship operations, the expansion of the work in the smaller countries, and, of course, the education of many people as to what the study of the ocean amounts to, not only in smaller countries but in the Halls of Congress.

FUTURE PLANS IN OCEANOGRAPHY

Finally, I might say a word about our future plans. As a result of the IGY and the experience gained and enthusiasm engendered, a new special committee of the International Council of Scientific Unions has

been established, a committee essentially like the IGY Committee, called the Special Committee on Oceanic Research. It hopes to continue international cooperation in the making of observations and planning of an assault, combined assault, on the oceans by the ships and people of different countries, not on a crash or intensive program like the IGY has been, but over a 10-year period.

One of the things that we are especially concerned about is to try to get ships of several different countries into the Indian Ocean. We would hope to have a joint expedition to the Indian Ocean in which some 16 ships from 11 different countries participate, probably in 1961, for a year.

This is an area which we really do not know anything about at all. The countries would be Russia, Japan, France, United Kingdom, Scandinavian countries, Germany, United States, India, Pakistan. I hope I have named 11. If not, there might be 1 or 2 others.

We are also concerned with such things as making joint experiments to follow large amounts of radioactive materials to see if we can work out a scheme for dumping, say, a million or so curies of radioactive materials into the deep sea with tracers to follow the current. This would require international cooperation. There are many problems requiring different countries to work together.

Mr. THOMAS. Thank you.

OCEAN TIDES

Mr. JONAS. Would you briefly explain exactly how the moon affects the tides?

Dr. REVELLE. The moon pulls the water. This is the earth; this is the moon. There is, essentially, an envelope of water all around the earth. That envelope is pulled toward the moon. The earth is also pulled toward the moon, so that you have a bump of water right under the moon and another bump of water on the opposite side because of the gravitational pull which tends to hump up the water, so you have low tide here and here, and high tide here and here. The sun does the same thing. When the sun is over here, when the sun and moon are pulling in the same direction, as they are about every 2 weeks with the full and new moon, you have exceptionally high and exceptionally low tides. When the moon is at the quarter and the sun here, we have mean tides.

This is complicated by the fact that the ocean really does not cover the earth. The ocean covers two long canals, namely, the Pacific and Atlantic Oceans, with land in between. The only place where the oceans circle the earth is around Antarctica. So, going up these canals from Antarctica you have a kind of progressive wave like you see on the surface, which moves, so that you do not, in general, have what are called equilibrium tides or pure gravitational tides, but you have tides complicated by the resonance of these canals.

OCEAN SEICHES

Mr. YATES. Would you explain to me what a seiche is? We were warned of one in Chicago over Saturday. A few years ago we had one that swept the fishermen off the rocks and drowned about 6 or 7 of them.

Dr. REVELLE. Seiche is a wave; it is a resonant effect. You have a slight impulse which is repeated at the entrance, like, for example, rise and fall of atmospheric pressure. This will cause a wave which may be quite big at some parts of the wave and quite small at other parts of the bay or arm of the sea. These are caused by what are called earthquake or seismic waves or any phenomenon that changes the level of the water at one place; this wave tends to propagate if it is in the right frequency, the right period for the body of water, so that the body of water resonates. Then you might get a big effect.

IGY STIMULUS TO INTERNATIONAL COOPERATION

Mr. YATES. My second question stems from the proposed experiment in 1961. The committee has asked questions about the cooperation between the United States and Russia in terms of the interchange of information.

You indicated that in an 11-country expedition that is proposed in 1961 India and Pakistan would be among the countries. There is some question as to whether they cooperate as well in other fields. I wondered if somebody can state what effect the International Geophysical Year can have in terms of possibly bringing about political rapprochement between such countries?

Dr. REVELLE. As you know, Mr. Yates, scientists always tend to be more internationally minded than many other people. During our Revolutionary War Benjamin Franklin was Postmaster General; he was a scientist as well as a great politician. He had orders issued concerning Captain Cook of the British Navy, who was then exploring the Pacific, that if any American ship ran across him they were to give him all aid and comfort, not to regard him as an enemy but regard him as a man advancing the cause of human understanding and knowledge.

During World Wars I and II the astronomers continued to cooperate all over the world. All during the cold war Harry Wexler and his opposite number in Russia have been exchanging weather information.

I would like to think, but I am afraid I do not think, that international scientific cooperation has a very direct effect on bringing Mr. Nehru and Mr. Ali Khan very close together.

Mr. YATES. Have you had no experience with whether they are cooperating or what they are doing?

Dr. REVELLE. They are cooperating through the International Geophysical Year Organization, not so much directly.

Dr. WATERMAN. The IGY itself was a good illustration of how the pattern can be established starting with the scientific unions. If they develop a program and ask the different countries to take part, then it becomes a matter of international cooperation on a scientific program for which the countries give approval and agree to support.

Mr. THOMAS. Did we not agree this morning that perhaps to date one of the outstanding characteristics of the International Geophysical Year has been to show to the world just how people can get along together and cooperate together?

Dr. REVELLE. That is very true.

Mr. THOMAS. We think perhaps you gentlemen have been of inestimable value to the State Department if they will take advantage of some of your techniques.

PERMANENT GEOPHYSICAL WORK

Mr. YATES. In your testimony this morning did you cover the possibility that the International Geophysical Year may be extended to become a permanent International Geophysical Institution?

Dr. KAPLAN. This has come up in some questions on what happens after the IGY. The point Dr. Revelle just brought out of the establishment of this Committee on Oceanography and establishment of the Committee on Antarctic Research, each with parallel committees, and the possible establishment of an International Committee on Rockets and Satellites illustrate this. There are many permanent services of other groups that will carry on the work certainly on an enhanced basis but we have not discussed it in terms of the committee extension of the program as such.

Certainly the impact of geophysics on our national picture of science has been felt greatly and much will be done afterward. I called attention to some immediate plans of the committee to make sure there is not a hiatus in certain immediate areas. We do not want to lose time or opportunities to capitalize. In this sense in part perhaps we have——

Mr. YATES. I am sure before your year comes to an end some thought will be given to the possibility of making it a permanent institution at a later time when you have had an opportunity to appraise what has been done. I agree with Mr. Thomas that this undertaking deserves to be placed on a permanent basis if it helps foster cooperation between nations in maintaining foundations for peaceful interchange between nations.

Dr. KAPLAN. We do not disagree with you.

Dr. WATERMAN. In selected fields of research where it is important to carry on, you would expect it to take place.

Dr. KAPLAN. It is important to make sure we do not lose time or opportunities at least for the present. There is the increased realization of the meaning of geophysics apart from the fact that several of you have been kind enough to raise, which is the example of international cooperation.

Mr. THOMAS. Dr. Kaplan, who is next?

IGY PROGRAMS IN SEISMOLOGY, GRAVITY, AND LONGITUDES AND LATITUDES

Dr. KAPLAN. We have asked Dr. Tuve to talk about three areas of the IGY, relating to the solid earth itself, seismology, gravity, and longitude and latitude. He is a member of the United States National Committee.

Mr. THOMAS. We are delighted to have you.

(The prepared statement of Dr. Merle A. Tuve follows:)

IGY SEISMOLOGY, GRAVITY, AND LONGITUDE AND LATITUDE PROGRAMS

It gives me great pleasure to appear before this committee to report on the work which has been done during the International Geophysical Year to learn more about the structure of the earth. I should like to discuss in detail the expeditions which have made seismic studies at sea, in the rugged Andes Mountains of South America and in hitherto unexplored regions of Antarctica in an effort to outline the structure of the uppermost portions of the earth and to try to understand why this structure differs from region to region. I shall mention

also the station seismologists who have developed instruments capable of measuring remarkably long period earthquake waves and the crustal strains resulting from earthquakes and from earth tides.

I shall also discuss the study of gravity, especially the work now being done with the new Graf sea-surface gravimeter. From the study of the earth's gravitational field, we shall learn more about the figure of the earth and the distribution of mass both on and within the earth.

Finally, I shall mention the program in longitude and latitude. This work will directly improve our geodetic and time standards, and will set the basis for future comparisons in the study of possible changes in the positions of the continents.

SEISMOLOGY

Oceanic

Seismic sea exploration of the Southeast Pacific Ocean was conducted under the direction of Dr. Russell Raitt, of the Scripps Institution of Oceanography during the recent downwind expedition, October 21, 1957, to February 28, 1958. The research vessels *Horizon* and *Spencer F. Baird* carried out the work of this expedition, logging a total of about 40,000 miles during the 4 months of the expedition. The program included measurements of carbon dioxide, chemical and physical properties of the water, bottom sounding, dredging, coring, photography, heat-flow measurements and seismic reflection and refractions studies.

Thirty-nine seismic refraction stations were recorded from the Tuamotu Archipelago to the west coast of South America. The object of the seismic profiles was to determine the crustal thickness and composition under the Pacific Ocean. In the Tuamotu Islands, normal oceanic structure (thickness 6 kilometers) was found despite the presence of shallow water areas on all sides. In a basin just east of the Easter Island Rise, one of the thinnest crusts yet found was revealed by the seismic records. Here the total crustal thickness under the sea floor was about 4 kilometers. Off the coast of Peru and Chile, under a subsurface ridge known as the Nasca Ridge, the expedition found the unusually great crustal thickness of 15 kilometers.

In addition to the customary crustal layer whose velocity is approximately 6¾ kilometers per second, the expedition found at most seismic stations a second layer directly underlying the ocean sediments with a velocity averaging 5 kilometers per second and thickness averaging 1 kilometer.

Continental: South America

As part of the IGY program in the measurement of continental structure Carnegie Institution of Washington undertook an expedition under the direction of Dr. Merle A. Tuve and the late Dr. Howard E. Tatel to make a seismic study in the Andes.

It has been the customary view of geologists that mountains and high plateaus are supported by a substructure of lighter crustal rocks extending downward into the heavier rocks of the earth's mantle, causing mountains to "float" in an isostatic balance, much as icebergs boat. During investigations in the Western United States in 1954, members of an expedition conducted by the Carnegie Institution of Washington found strong indications that another kind of substructure may also hold mountains up. A network of relatively narrow roots or veins of lighter crustal rock may project into the earth's mantle, the layer beneath the crust, to depths as great as 200 kilometers.

To test this idea elsewhere, the Carnegie Andes Expedition for the IGY during the summer of 1957 undertook investigations of the high regions of Peru, Bolivia, and northern Chile. Their immediate aim was to attempt to determine the character of the roots of the Andes by measuring the waves from explosions used in the great open-pit copper mines of Peru and Chile.

Members of the 1954 Carnegie field party in Arizona, New Mexico, and Utah had discovered that the thickness of the crust—as shown by strong reflections of compressional waves from the upper surface of the mantle—is about the same under the high Colorado Plateau as under the much lower plains and mountains of the Eastern United States. This thickness of crustal material, 29 to 34 kilometers, was also found under still higher Alaskan mountains on a 1955 Carnegie Expedition.

Two areas of the globe other than the Colorado Plateau region are characterized by a huge mountain bulk supporting an extensive elevated plateau—the Himalayas in Tibet and the Andes of southern Peru, western Bolivia, and northern Chile. The Andes, where thousands of cubic miles of rock rise to form a tremendous 12,000- to 16,000-foot plateau called the altiplano, were chosen as the site for a continuation of these studies.

In several of the Peruvian and Chilean copper mines single shots of 40 to 60 tons of dynamite are exploded almost every day. These explosions produce elastic waves, especially compressional waves, which pass through the crustal rocks and the higher-velocity rocks of the mantle below the base of the crust. It was hoped that observation of these waves, both those traveling along lines parallel to the mountains and those traveling across and beneath the mountains, would provide some clues to the character of the deep-lying structures that support these towering mountains.

During the months of August, September, and October 1957, members of the expedition made measurements and recordings at more than 200 carefully selected locations deep in the mountains of Peru, Bolivia, and Chile. Radio timing techniques were used for observing the waves from nearly 60 large explosions.

Detailed studies of the seismic records have not yet been completed, but the wave measurements indicate that the Andean structures are highly nonuniform. An unexpected difficulty was encountered: the 50-ton explosions were not large enough to permit outlining of the structures deep under the altiplano although the seismographs were capable of recording ground motions smaller than two billionths of an inch. In North America motions 1,000 times greater than this were normal. Measurements of actual depths to the M-discontinuity (base of the crust) by observing strong reflected waves were successful only in limited sectors along lines more or less parallel to the mountains. Suitable observations directly across the mountains were not obtained in spite of weeks of intensive effort.

In Peru, beneath regions with average elevations of 9,000 to 10,000 feet, the thickness of the crust appears to be 34 kilometers, approximately the same as under the Rocky Mountains in the United States and Alaska. However, in northern Chile, again along lines roughly parallel to the mountains, in an area with an average elevation of only about 5,000 feet, the strong reflections showed a thickness of about 55 kilometers.

The apparent velocity in the rock below the reflection discontinuity in each of these areas is similar to the expected velocity of about 8 kilometers per second for mantle rocks. As in all measurements of mantle velocities, however, nonuniformities in the overburden of 30 kilometers or so of crustal rock in the Andes effectively prevents precision measurements of the velocity of the mantle. During the past several years there has been a growing realization that the idea of a single, worldwide value of wave velocity for the outermost portion of the mantle is probably an erroneous simplification.

The principal result of this seismic reconnaissance, then, is the indication that there appear to be nonuniformities and regional geographic differences in the mantle of the earth, just as there are in the crustal rocks. Under northern Chile, it appears that the lighter rocks of the crust project downward to nearly 55 kilometers. This by itself is enough to float the mass of the Andes overhead. On the other hand, in southern Peru, the crustal rocks extend only to the normal depth of 34 kilometers, and the towering Andes in that area are presumably held aloft by more diffuse roots projecting as much as 200 kilometers into the mantle itself, or at least far below the levels where reflections of the explosion waves could have been observed.

Continental North America

During the summer of 1957, the University of Wisconsin undertook seismic refraction studies in the Central Plateau of Mexico. The preliminary results of this work indicate that plateau regions of continents have a crustal thickness of 39 kilometers determined by seismic means, which is slightly less than the thickness estimated from gravity studies. This is somewhat greater than the thickness found for the Colorado Plateau by the Carnegie Expedition. As a continuation of the study of continental crustal structure, the group at Wisconsin under the direction of Dr. George P. Woollard plans to make seismic measurements of the crustal thickness in northern Wisconsin and western Michigan, an area in which gravity studies predict a relatively thin crustal structure.

Long period waves

Another part of the IGY program in seismology has been the installation of a worldwide network of special long period seismometers of a type recently developed at Lamont Geological Observatory and the California Institute of Technology. These long period instruments have revealed the existence of important energy components in seismic waves with periods greater than 50 seconds. There long waves correspond to propagation types not hitherto recognized, including Rayleigh waves with periods of 600 seconds, and low velocity

waves with periods of 200 seconds which are still unexplained. These long Rayleigh waves penetrate deeply into the earth's mantle yielding information on the structure of the earth not available from other wave types.

Long period seismographs have been installed in 10 stations distributed around the world: Uppsala, Sweden; Lwiro, Belgium Congo; Poona, India; Hong Kong; Tokyo, Japan; Honolulu, T. H.; Suva, Fiji Islands; Santiago, Chile; Buenos Aires, Argentina; and Rio de Janeiro, Brazil. Similar installations have been made in cooperation with the Canadians at Resolute Bay in the Northwest Territories and in cooperation with New Zealand at Cape Hallett in Antarctica.

It appears that a study of the greater frequency range of seismic waves which these instruments will make available, coupled with detailed theoretical results now becoming available as a result of the application of high speed computing technique, will yield information on the variation of elastic properties in the earth's crust and mantle.

Earth strain measurement

Closely related both to the long period seismograph and to the earth tide gravity studies are the seismic strain gauges or extensometers.

Two fused-quartz extensometers, relatively new instruments for measuring earth strain, have been installed at locations in the Andes Mountains as part of the United States-IGY program in seismology. The project is directed by Hugo Benioff of the California Institute of Technology. The observing stations are operated by the University of Chile and the Peruvan National Committee for the IGY.

Standard seismometers, which have been used since the late 19th century, record ground motion during the passage of elastic waves, whose source may be either an earthquake or an artificial explosion. The extensometer, or strain seismometer, on the other hand, measures the differential motion between two nearby points (the ends of the extensometer). The change in the length of the extensometer, either increase or decrease, when divided by the original length, represents the change in strain.

The first extensometer employed for routine observations was designed and installed by Benioff more than 20 years ago. This instrument used an iron pipe as a length standard. About 10 years ago, a redesigned version, using a fused-quartz rod as a length standard was installed at Isabella, Calif. The quartz rod greatly reduces undesirable variants caused by temperature fluctuations. The South American extensometers are of this type.

One of the new extensometers is located as San Cristobal, in the outskirts of Santiago, Chile; the other is in Chosica, a small settlement some 20 miles from Lima, Peru. The University of Chile, at Santiago, and the Peruvian National Committee for IGY, at Chosica, have excavated the tunnels in which the instruments are located, are providing electric power at the sites, and are supplying personnel for the operation of the stations.

Each installation consists of two horizontal extensometers mounted at right angles in tunnels bored into igneous rock. The length standards are constructed of fused-quartz tubing 25 meters in length. These instruments have a sensitivity capable of detecting an earth strain equivalent to a change in distance of one-tenth inch in 2,000 miles.

The extensometers will provide three kinds of observational data: Measurements of secular (long-range) strain changes occurring in the great Andes Mountain Range; measurements of the tidal (diurnal) strain of the earth produced by the gravitational action of the sun and moon; recordings of ultra-long-period seismic waves, including possible free vibrations of the earth excited by earthquakes.

Measurements of tidal strain provide information on the elastic and plastic properties of the outermost portion of the earth. The long-period waves yield information concerning the mantle and core of the earth as well as the mechanism of the generation of earthquakes.

Measurements of secular strains and their accumulation, made at an adequate number of stations over a long interval of time, may yield sufficient information to determine the strain pattern and habit of a region. It is conceivable that such knowledge might ultimately provide a basis for the prediction of earthquakes. The time required for such a study, however, might run into several centuries.

Antarctic station seismology

Station seismographs were established at four of the United States stations in the Antarctica: Wilkes, Byrd, Amundsen-Scott (South Pole), and, in cooperation

with New Zealand, at Capa Adare (Hallett). Records from the first year have recently been returned to the United States for reduction and analysis. These records are the first seismograph records of earthquake waves ever obtained in Antarctica. The results from these records will enable existing travel-time curves for the Pacific region to be confirmed or modified. Since the majority of earthquakes occur in the borders of the Pacific, this information is fundamental to earthquake seismology. In addition, these records will yield information on the structure of the Antarctic region itself at depths from which seismic waves from explosions cannot return to be recorded.

Antarctic oversnow traverses

Although 11 nations have established 38 new scientific stations in the Antarctic for the IGY, observations made at these widely-distributed stations can furnish only a portion of the geophysical data needed for a complete understanding of this 6 million-square-mile region of ice and rock. To fill some of the major gaps, a series of oversnow scientific traverses were organized as part of the United States-IGY Antarctic program for the summer seasons of 1957–58 and 1958–59.

Three major oversnow traverses scheduled for the 1957–58 summer season by the United States-IGY have been completed: the Ross Ice Shelf traverse from IGY Little America Station; a traverse of parts of Marie Byrd Land and the Ellsworth Highland from IGY Byrd Station; and a traverse across the Filchner Ice Shelf and parts of Edith Ronne Land from IGY Ellsworth Station. They were preceded in January and February 1957 by a tractor-train traverse from Little America to Byrd Station, 647 miles eastward over the icecap. Glaciologic and seismologic measurements were made on this first traverse; experimental and logistic procedures and techniques were tested and perfected.

In the traverse program seismic techniques are used to measure the thickness of the ice and to determine the character of the subglacial floor and of exposed land areas. Ground control, for subsequent survey operations, is established wherever rock outcrops occur. Gravity measurements, partly in association with the seismic work, and measurements of the earth's magnetic field strength and of magnetic compass variations are included in the basic traverse programs. Airborne seismic and glaciological traverses, to make spot measurements in areas inaccessible to surface parties, are also part of the program.

The early traverse from IGY Little America Station to Byrd Station resulted in the first extensive evidence that the Antarctic Continent is overlaid with a far greater volume of ice than long thought. (Byrd Station, about 5,000 feet above sea level, rests on about 10,000 feet of ice.)

Gravity and seismologic data obtained on these traverses may show whether the sub-sea-level portion of the ice sheet, such as exists beneath Byrd Station, occurs in fjord-like depressions similar to those found to exist under the Greenland icecap and Queen Maud Land or indicates the presence of a great frozen sea in West Antarctica.

Although geologic study reveals that the Antarctic ice mantle was once about 1,000 feet thicker than it is now, it is not yet known whether the total ice mass is at present increasing or decreasing.

Data acquired on the traverses will also contribute to knowledge of the relationships between Antarctic ice and the supply and movement of cold ocean waters, as well as between the ice and Southern Hemisphere weather and climate. Data from the traverses are now being reduced by a team of the men who made the observation under direction of Dr. George P. Woollard at the University of Wisconsin.

IGY Little America Station.—The traverse party from Little America had as its objective during the past season the study of the mass and volume, thickness, hydrologic economy, morphology, and structure of the Ross Ice Shelf. The depth to the sea bottom beneath the floating ice shelf was measured by seismic methods, investigations were made of mountain ranges and peaks along the edge of the shelf, and wind-drift or sastrugi-patterns were studied.

The traverse party, consisting of eight men led by Albert P. Crary, station scientific leader at Little America and deputy chief scientist for the USNC–IGY Antarctic program, left its home station on October 24, 1957.

The Ross Ice Shelf extends more than 400 miles into the Ross Sea embayment from a point about 300 miles from the South Pole. Its maximum width is approximately 500 miles and its area about 160,000 square miles. Recent seismic studies by IGY scientists at Little America Station made in the vicinity of the station but away from the edge of the shelf, shows an ice thickness ranging from

nearly 790 to about 1,050 feet. The ocean bottom was shown to be about 2,070 to 2,155 feet below the ice surface, indicating that this part of the shelf floats on well over 1,000 feet of water. It has been estimated that the shelf moves seaward at the rate of about 5 feet per day.

Elevation of the ice surface was measured continuously along the traverse route by the altimetry leapfrog method, which employs three crews to make successive atmospheric pressure measurements at each site. Sites occupied are 5 miles apart. This method provides enough data for each position to permit corrections for fluctuations in atmospheric pressure, allowing much more accurate altitude determinations than would be possible with single observations.

Employing this technique, the Ross Ice Shelf traverse party found that the shelf's elevation varies overall by about 60 feet. In general, however, the ice shelf appeared virtually featureless. Only two small islands, situated just west of Roosevelt Island, and two small depressions broke the evenness of the ice surface during the first leg of the route.

The traverse party returned to IGY Little America Station on February 13, 1958, after 113 days in the field. The overall length of the traverse was 1,450 miles.

IGY Byrd Station.—The broad objective of the Byrd Station traverse for the 1957–58 summer season was to determine the general nature of the ice sheet and of protruding mountains in eastern Marie Byrd Land and in the Ellsworth Highland to the east of Byrd Station. Although specific types of measurements were similar to those made on the Ross Ice Shelf traverse, the existence of thousands of feet of inland ice resting on a bedrock surface in the region covered by the Byrd party constituted a major environmental difference.

The Byrd Station traverse party, led by Vernon Anderson, IGY glaciologist, departed on November 19, 1957. Excellent seismic reflection data were obtained throughout the traverse. At distances of 100-200 miles west of the Sentinel Mountains, the apex of the second and third legs of the traverse, ice thicknesses were generally more than 10,000 feet; the maximum measured was 11,610 feet. The seismic records for most of the traverse route indicated rugged, variable topography characterizing a subglacial floor almost everywhere below sea level. One unusual biological observation was the discovery of penguin tracks along the traverse route at a point more than 150 miles from the nearest known coast.

The traverse ended on February 23, 1958, with the return of the party to IGY Byrd Station after 96 days in the field and a trek of about 1,200 miles.

IGY Ellsworth Station.—The Ellsworth Station traverse investigated the Filchner Ice Shelf and the inland ice of Edith Ronne Land, combining the types of measurements made by both the Little America and Byrd traverses. An important goal of this traverse was to occupy a point that could also be reached by next summer season's Byrd station traverse, thus providing a link of the correlation of data.

The traverse party left IGY Ellsworth Station on October 28, 1957, led by Edward C. Thiel, glaciologist. The party had been held up several days while airborne efforts were made to find a safe passage through a heavily crevassed area in the first 50 miles south of Ellsworth Station. A crevasse-free passage towards the east and with elevations of 700 to 3,000 feet above sea level was found.

The party deviated about 120 miles from the planned route to make geological studies and collect rock specimens at a newly reported mountain range. The range, estimated to be 11,000 feet high in places, is reported to be about 400 miles from the South Pole, trending east-west throughout its length of about 100 miles. It was discovered from the air by Finn Ronne, then scientific leader at IGY Ellsworth Station.

A 3,200-foot ice-covered island extending for about 230 miles south and west from Gould Bay was observed for the first time. Seismic soundings showed the land surface beneath the island's ice mantle to be hundreds of feet above sea level. Other islands, whose contours were not fully delineated, were seen still farther westward.

In early January 1958 the traverse had covered 816 miles, including a large portion of the Filchner Ice Shelf and considerable inland stretches. The party backtracked to the midpoint station, where the vehicles and equipment were cached for use by next year's party.

Other traverses.—1957–58 personnel remaining at US-IGY Antarctic stations conducted several short traverses in the vicinities of their stations during the 1957–58 Antarctic summer season. The aims were basically similar to those of major traverses.

Trans-Antarctic Expedition.—Using the US-IGY South Pole Station as a linkage point, a combined United Kingdom British expedition was conducted during the past Antarctic summer, completing the first continental crossing of the Antarctic.

The United Kingdom party, led by Vivian E. Fuchs, left Shackelton Station, on the Weddell Sea, on November 24, 1957; it arrived at the South Pole on January 19, 1958. This was the first time the regions between the Weddell Sea and the South Pole, a distance of more than 2,000 miles, had been crossed overland.

The party left IGY South Pole Station on January 24 and reached Scott Station, the terminus of the traverse, on March 1, 1958. Seismic studies made by the Fuchs party should provide the first profile of the ice thickness, surface elevations, and subglacial surface across Antarctica from the Weddell Sea to the Ross Sea.

GRAVITY

The earth is the attracting mass for all bodies on the earth. The earth, however, is not a perfect sphere, nor is its mass uniformly distributed. Furthermore, it is rotating. These conditions add up to the fact that gravity is not uniform and constant all over the earth. In general, because of the fact that the earth bulges somewhat at the equator and centrifugal force is greatest there, gravity is least at the equator and increases toward the poles. This effect is large enough to make a 200-pound man weigh 1 pound more at the pole than at the equator. In addition to this nonuniformity, great continental mountain masses, underground ore bodies, underseas mountains, and, in general, the uneven distribution of mass around the crust of the earth, contribute to local anomalies, some of which may be sufficiently large to deflect a plumb bob away from the vertical. Although this deflection is less than 10 seconds of arc, there are a few locations—Puerto Rico is one—where it exceeds 1 minute. This effect is significant in geodesy wherever geodetic control depends on astronomical observations.

The IGY program in gravity is aimed at increasing the reliability of measurements of gravity over the world, particularly in providing very accurate and reliable measurements at certain key locations to provide connection points between the gravity networks of various countries. Many measurements have been made already, including observations in the Arctic basin taken from United States IGY stations on the drifting ice. An important new station is located in Antarctica, where first-order measurement of gravity was made to provide a calibration for future measurements in the interior.

As the moon rotates around the earth and the earth rotates around the sun, the solid earth undergoes the same kind of tidal bulging that occurs in the oceans, although, of course, by a much lesser amount. Yet, it is enough to be observed with the most sensitive gravimeters. As the earth heaves in tidal motion, the distance of a point on the surface from the center of the earth changes by a small amount, perhaps a few tenths of an inch to several inches. This can be detected directly by instruments which are now in use recording the "pulse" of the earth, instruments which are sensitive to 1 part in 1 billion of the average value of gravity.

Sea surface gravimeter

The first successful surface measurements of gravity in the open sea were made on November 22, 1957, by J. Lamar Worzel, assistant director of the Lamont Geological Observatory at Columbia University, using a new sea gravimeter developed by Anton Graf, of Munich. The instrument was mounted on a gyro-stabilized platform installed aboard the U. S. S. *Compass Island.*

Gravity values for ocean areas have, in the past, had to be measured in submarines submerged to quiet depths. Difficulties in obtaining and fitting submarines for this purpose greatly restricted the accumulation of gravity data for the 70 percent of the earth's surface that is covered by water. The new sea gravimeter now makes it possible to take gravity measurements simply and expeditiously in moderately calm seas any place on the ocean surfaces of the earth, thus assuring that data long needed but difficult or impossible to obtain will now be available.

To date there have been only about 5,000 measurements of gravity made at sea throughout the world. A device for multiplying the volume of such data is therefore of the greatest importance for the objectives of the IGY gravity program. This program seeks (1) to fill in the major gaps in a world gravity

network, principally in the Arctic, Antarctic, and ocean areas, and (2) to relate existing networks, generally national in character, to each other so as to produce a first-order international network. Attainment of these objectives will greatly improve gravimetric mapping, which offers the fastest and most accurate method for linking all maps to a common reference system, and add much to knowledge of the earth's shape and the distribution of its mass.

Roughly half of the existing sea surface gravity measurements have been made by the Lamont Geological Observatory in the past 10 years using pendulums carried in submerged submarines. Gravity measurements at sea were begun as recently as 1927 by Vening Meinesz, who developed a pendulum apparatus for use on the spongy soil of Holland. Vening Meinesz found that his pendulums could be used in submarines to take gravity readings in the open sea, and it was he who made most of the 1,200 oceanic gravity measurements recorded by the end of World War II. Since the end of the war, British and Dutch scientists, in addition to those at Lamont, have conducted submarine gravity programs.

The U. S. S. *Compass Island* left New York November 18 and returned November 22. To evaluate the accuracy of the Graf sea gravimeter, which had previously been tested on a surface ship only on a lake and the Adriatic Sea, the surface measurements were begun 200 miles southeast of New York on November 22, at a point where measurements had been taken aboard the submarine U. S. S. *Tusk* in 1947. The surface measurements were continued on a track which closely duplicated the *Tusk's*, moving from the deep ocean basin across the Continental Slope and onto the Continental Shelf, ending off Fire Island, N. Y.

The new sea surface gravimeter has additional advantages over the standard submarine pendulums. Surface gravity measurements from the U. S. S. *Compass Island* were taken in 9 hours, as compared with 2 days for earlier submarine measurements of comparable areas. The data were reduced in just one-half day, as compared with 2 weeks needed to adjust and compute data from submarine measurements.

Lamont scientists plan to continue to test the Graf sea gravimeter throughout the IGY, and they hope that it will eventually take its place aboard all oceanographic research vessels and become a standard method of gravity measurement.

LONGITUDE AND LATITUDE

Scientists of 29 countries at 45 stations around the world are in the process of determining longitude and latitudes more precisely. Besides observations at 3 stations using the Danjon impersonal astrolabe, the United States is furnishing 20 of the moon position cameras developed at the Naval Observatory in Washington, D. C.

The latitude and longitude program consists of two distinct programs: the astronomical longitude and latitude program carried out principally with the Danjon impersonal astrolabe, and the moon position program, carried out with the moon position cameras.

The United States Naval Observatory is primarily concerned with the moon position program. Data are obtained in the form of photographic plates from 20 observatories equipped with moon position cameras. The plates are to be processed in a preliminary manner and sent to 1 of 4 measurement centers, in Washington, Cape of Good Hope, Paris, and Herstmonceux. After the plates are measured, the measurements are sent to the Naval Observatory for further processing using a high-speed computer. The results of these computations will be published in the standard form: right ascension and declination of the moon at the universal time of observation. These observations will permit a precise location of the earth's land masses within an accuracy of approximately 100 feet. The moon position program will also determine a more precise value of uniform (Ephemeris) time which will be applied directly to the calibration of Cesium atomic frequency standards.

The astrolabe program which makes relative position determinations to accuracy less than 10 feet will set a basis for future comparisons in determining whether land masses are shifting with respect to one another.

Dr. TUVE. Before I start to report on seismology and gravity, I would like to make a comment. The remark was made this morning referring to our first meetings in 1954 and 1955, the remark was made

that the program has been pretty well carried out. Actually a lot more has been done than was planned.

As you will recall, this whole IGY started at the time when it was not clear it would be more than half the world involved. When Russia came in and other countries jumped on the bandwagon it expanded to be quite a large activity.

COORDINATED SUPPORT FOR IGY PROGRAM

I should like to comment that now I am speaking not primarily as a member of the committee but one of the field workers. It has been very well handled. We have been very well supported by the National Science Foundation and the Congress, the Budget Bureau, and, of course, by the various departments, the operating parts of the Government such as Air Force, Navy, and Army. It has really been quite an experience in community activity. We have been much better handled than I think I would have pictured it as being possible under any kind of a benevolent prince or duke. In the old days art and exploration and music were the province of the men in power.

There are a dozen of us. We have been involved in explorations in various parts of the world. It takes a dozen to do it. We are reporting to a group of men who are wielding the power for the community that was in the old days handled by the dukes and the princes. This is to me a very satisfying day because we are not here just to get money from the Congress but are trying to tell you what a pleasure it has been to carry out some of the things for the people of the United States.

Mr. THOMAS. You are a remarkable man. This is the best meeting we have had. You will have to come here again. Not a man in this room got out of his chair for 2 hours and 40 minutes this morning and I noticed the facial expression of everybody here and each man was just as interested in what everybody was saying.

Dr. TUVE. We like to think, too, that all the people in the United States are sharing in the ideas and curiosity and the questing or searching we have been doing, just as they have been sharing the cost. This, too, I think is a change from the old days.

I could not help but comment on the way in which this represents a pleasurable opportunity for us because we are in midstream, IGY is still going on. You gentlemen and all of us have had in mind the question: If this has been a kind of social good, one of the things we are glad to support, one of the products of our culture that we can be proud of, how can we make sure we foster it in the future? All we are doing today is trying to share with you and therefore perhaps the other people of the country the pleasure we have had in carrying out these kinds of things.

I am supposed to talk to you about the programs in seismology, gravity and on the measurements of position on the globe. A good deal of the material that comes in here in our particular panel has been covered one way or another in discussing the thickness of the ice in the Antarctic and of the ocean floor. These measurements have been carried out by the seismological people to a large extent.

Let me say I am going to talk briefly about the measurements in the ocean, the measurements in continental South America, also in Mexico, and the data on the thickness of the ice in the Antarctic. Of course it is

not all worked up yet. You heard this morning a little over 2 tons of data from the Antarctic arrived last week. That has not yet been brought into the field where we can discuss it. A lot of these measurements require quite detailed computation before having a final answer.

MEASUREMENT OF GRAVITY AT SEA

One of the really striking things which is really an investment in the future, I think, for geophysics—I am proud of it because I was pushing real hard on this in the beginning of the IGY—is the Graf sea gravimeter. The sea gravimeter is an instrument you can put on an ordinary surface vessel and measure the acceleration of gravity. The acceleration of gravity is measured to about one millionth of the weight of a body, which is the accuracy of the measurement in spite of the fact that the acceleration on the deck of the ship can be quite large, one one-thousandth of a weight of the body, yet it takes an average so accurately that by cruising a mile or a mile and a half they get a measure to one part in a million of the acceleration of gravity over that part of the sea. It came out unexpectedly. We had planned at the beginning of the IGY to work on electronic gadgets developed over 6 or 8 years at Cambridge, England. It was simply a taut wire which vibrated at a certain rate depending on the weight hung on it. When that mass changed its weight by being in a different gravity field the frequency of the wire would change a little.

This had been tried in submarines and so on but it looked as though it might make it possible, using electronic devices, to get a very good average. It worked out much more simply than that. Professor Graf used a very highly damped pendulum, an old idea in the textbooks since 1880. He carried it out on a lake. Dr. Worzel at Columbia heard about this. We were still pushing, trying to get some work done on the electronic device. Worzel called me one morning and said he had heard about this instrument; and, as one of the members of the panel I said, "Can you visit him and find out this week what this actual status is?" He had heard a rumor. He said, "No, I give a Ph. D. exam on Friday, I have to be here Saturday." I said, "This is only Tuesday night." He jumped on an airplane the next morning, spent about 8 hours in, I think, Switzerland at Lake Geneva where the man was making tests and was back here Friday morning.

That led to this development which finally worked out in the testing by this Columbia group. We are pleased to put it on the Compass Island down in the Mediterranean but they have been making some trips between New York and Bermuda over paths where they had previously measured in submarines.

The submarine gets down low enough that the ocean waves don't bother it. The problem has been to know exactly how fast it is moving. Some of the more modern ways of measuring subsurface currents have been applicable.

At any rate the best measurements of the acceleration of gravity are the only ones which have been made in submarines.

They covered the path which had previously been covered by the submarine and I would say, having looked at the records, that probably it is true that the measurements on the surface vessel are better than the ones that were made on the submarine, because this submarine, making measurements over several paths, encountered

subsurface currents which moved it about 1 or 2 miles an hour, whereas the surface vessels measure accurately where they are at all times.

I think this will revolutionize our knowledge of the earth's surface in the course of maybe 10 years of observation, because by putting a stabilized platform—it is a very precise version of a gun platform—on just any kind of ordinary cruise ship, you can go wherever surface vessels travel and make accurate measurements of gravity.

This is one of the things we shall be able to share with other countries, developed by the German, Graf. We are testing it and carrying it out. I believe this will be one of the things that the United States effort in the IGY will hand on to geophysics, a great payoff in the next 10 years.

Mr. YATES. We are in a field of basic research, I know, but I am trying to take the next step. What does this do? Now that you find differences in gravity as you go along, where does this bring you? You find that it varies. What is the next step beyond this knowledge, or are you not ready for that yet, having measured the differences in gravity?

Dr. TUVE. Aside from some purely practical things about navigation, I believe the real payoff is simply in the romance of the ideas. We are really concerned with the fundamental differences between ocean basins and continents. This has not been understood. Dr. Revelle referred to the fact that oceanographers and geologists are concerned with the early history of the earth. It goes back 3 or perhaps 4 billion years. We do not know the extent to which surface features which we see have been permanent. I think that gravity essentially is one of the ways by which we set limits on mechanisms which can have operated below the surface.

GRAVITY MEASUREMENTS AND EARTH STRUCTURE

For example, that is the reason we went to the Andes. I was with my late partner, Dr. Howard Tatel, in the Andes for 3 months last summer, August until almost November, making measurements to understand what it is that holds the Andes up, in fact, the Antiplano, this very high plateau which is tremendously impressive as you traverse it backward and forward by truck as we did. I do not know its limits, but I would say 1,500 miles, anyway, north and south, and about 400 miles wide where we crossed it. This is a very large number of cubic miles of rock.

The gravity measurements which we were also making were not new, for others had made a few of those before, showing that these mountains essentially are floating. It is not the strength of the earth's crust that holds them up. They are not held up as though they were on a table. But they are floating, much in the fashion of an iceberg.

The gravity measurements set limits on the mechanisms by which we can explain even the features we find now. The mountains are standing up high in certain parts of the world today. There are other places, such as right here, where there were mountains once and they are no longer sticking up in the air. We are interested in the causes deep below the surface which give rise to these great longtime changes.

It is part of the whole business of man feeling at home on this globe, I think. This is a fairly important thing.

Dr. REVELLE. Take a more specific case in point than yours. The only place you are really interested in the gravity is where it is not what it should be. As long as it is what it should be, then this is only of moderate interest. Take that trench along the South American coast that we were talking about today. The fact is that the gravity near that trench is very far different than what it would be if the earth were a simple inactive earth. There is something which is actually pulling that trench down against the force of gravity. It is as if you had a great giant standing in the interior of the earth pulling it down while the force of gravity wants to push it back again. It is these areas where the gravity is not what it ought to be that really give you very suggestive clues to what is going on in the earth and what the character of the rocks is and where the forces within the earth are active and are now operative.

We know from gravity this trench is actually active now. We know this from a lot of other things, but also from gravity. Right now there is a very strong force holding it down.

STRUCTURE OF THE EARTH'S CRUST

Dr. TUVE. That is a very small-scale phenomenon. It is long but very narrow. We are even at sea or puzzled about the very large features. As I said, one of the big problems for 50 years has been, What is the really basic difference between ocean basins and continents? Of course, there are very simple, glib answers that we know, but what the basic causes are is less clear. Our particular expedition, which is part of what I am supposed to report upon, was to the Andes and the plateau of Peru, Bolivia, and Chile, to ascertain, if we could, the boundary between the earth's crust and what is called the mantle of the earth, how deep that is. Right under the table here it is about 32 kilometers deep, a little over 20 miles. At that point there is an abrupt change in the character of the rocks. The velocity of the waves traveling in them changes from about 6.2 kilometers a second to about 8.1 kilometers a second. We get reflections from this boundary. We can send soundwaves. Many times we have had the Navy explode depth charges in Chesapeake Bay and we observe these waves as they come through the crust. The crust is the weathered rocks which have been subjected to volcanism and weather, and so on, for 2 or 3 billion years.

ROOTS OF MOUNTAINS

Down below that is heavier rock which we refer to as the mantle. It has not been clear whether they are uniform or not. The picture in the textbooks is that the mantle of the earth is uniform around the world. In that case you would picture the Rocky Mountains, for example, as floating like an iceberg. The ice is a little bit lighter than water. It sticks down a ways, and one-ninth of the iceberg is held up above the water. So there is a lot more below the water than above the water. Much the same effect should happen under the Colorado Plateau in the Rocky Mountains.

We have been looking for these roots of mountains for some years. In 1954 we made an expedition to Arizona, New Mexico, and Utah,

expecting to find the usual confusion. Many times scientific people try to measure something and they conclude that it is too confused or too complicated to draw any conclusions. We were startled out there to find that in this country, very complicated from the geological standpoint, there was one very clear thing; that the boundary between these crustal rocks and the mantle was about the same there as it is here. Yet there are 2 miles of rocks sticking up in the air on the Colorado Plateau.

We made these measurements in Arizona and New Mexico, and then we moved up by Salt Lake City and made similar measurements up near Salt Lake.

This gave support to another kind of idea besides the iceberg idea, namely, that underneath large mountain chains it could be that there was on the average a somewhat lighter, somewhat less dense mantle than there was, for example, under here. That also would give not quite so much mass from the center of the earth out to sea level as there is here. Since the gravity meters have shown that the Rocky Mountains were in floating equilibrium, with, let us say, 6,600 feet of rock, the rest of it is floating. There are anomalies that might correspond to differences in level of 600 or 800 feet. The strength of the earth is enough for that. But the strength of the earth is like rubber ice. If you ever skated on rubber ice when a youngster, it is like that. The crust of the earth yields over a distance on the order of 600 to 1,000 miles, enough that it would dimple in if the mountains were simply placed on it.

We knew they were floating. This gave the idea of geography in the mantle as well as geography in the crust. We look at the crust of the earth in various parts, and we see it is different from one region to another. Previously, and in the books, the best estimate had been the mathematician's estimate that the velocity is about eight. It seems to be pretty clearly that wherever we measure it. Of course, there is a margin of error from 7½ to 8½. We felt it was uniform.

We previously had gone to Alaska in 1956 and found similar results to New Mexico and Utah.

ROOTS OF THE ANDES

So as our part of the IGY—I am speaking quite personally because it was really a very great deal of satisfaction to go down there and do this as part of the international operation—we decided we would see if we could find where the boundary was between the mantle and the crust underneath the Andes. The Andes, and the Himalayas in Tibet, are the two conspicuous places on the globe where an enormous volume of rock is held up high in the air by unknown forces. The Andes had been measured in a few places for gravity, so we knew they were floating.

We arranged with our colleagues and opposite numbers in Peru, Bolivia, and Chile, that we would be invited to work there, and made use of the explosions from these large copper mines. They explode anywhere from 30 to 60 tons of explosives per day. We stationed a man at the mine who measured against the WWV time signals exactly when the explosion occurred. One hundred to four hundred miles away we also measured the arrival of the waves against the time signals.

I must say that all three of those countries did things for us that we could not do for our opposite numbers if they came here. As English-speaking foreigners we were allowed to operate our own radios. We were not citizens. If you look at the laws of the United States, not even a Canadian can use a portable radio in this country. If you use a radio you must be a citizen.

There were many ways in which they set aside their own country's laws in order to allow the IGY cooperation to happen. It was a very warm kind of thing. We were met at the borders. Customs officials in the South American countries are a little slow in approving things at times. I must say it was a tremendous relief to be helped through the borders by the fact that they were all anxious to participate in whatever way they could in the International Geophysical Year. We had men from all three countries with us at intervals in the field. Most of the work was done by our own teams. Numbers are limited there.

Very briefly, the results were perhaps less satisfying than the experience itself. We found confusion in the Andes. We did find reflections along the plane of the antiplano, both in Chile and in Peru. Although we struggled for weeks and made measurements there that were at least 20 times more sensitive than we ever did in the United States or Alaska, we could not find the waves which traveled across and under this huge antiplano.

We went down the plains down to Quebracho, but we could not find the waves on the far side.

CONTINUED WORK IN THE ANDES

We have arranged to continue the collaboration. We left our equipment there. We are arranging to go forward with a new set of earthquake measurements. Maybe 60 tons is not enough. They have bigger shakes scheduled. The earthquakes are not scheduled, but we can measure them. We are going to set up networks of about 10 earthquake measuring stations at Arequipa and Lake Titicaca and continue the measurements. We have arrangements with scientific people in each of these countries. The Chilean is coming up the middle of the month. The man from Peru, to make other arrangements, is visiting later in the year. We shall continue these relationships. It is still a puzzle.

The earth's crust was found under an average elevation of about 10,000 feet. Actually, the point of reflection was right under an active volcano 19,000 feet high. It was about the same as you measure under here, about 34 kilometers.

On the other hand, in Chile, where the average elevation where we were measuring was about 5,000 feet, it was 55 kilometers depth. I would say the Andes are complex and very interesting. It was a large order for 8 or 10 men and half a dozen trucks to do more than a quick reconnaissance in a few months. That will continue.

In order to share in a personal way, that is the kind of thing that went on in the year.

PACIFIC CRUSTAL EXPLORATION

Some of the most interesting measurements were made by Roger Revelle's men in the Pacific. This was a huge unknown area. Dr.

Raitt, of the Scripps staff, has made measurements of the Moho depth in this enormous area, a whole series of very interesting ones, from Tuamotu Island east to the coast of South America. They cover quite a range of things. In the islands themselves it was a perfectly normal depth, in spite of the fact that it looked almost like continental structure around there.

The differences that we find are uniform or reasonably uniform over the world. Under continental structures this boundary between the slower rocks and the fast ones, between the lighter rocks and the heavier ones, is 35 kilometers deep, roughly. Under the oceans it is only about 11 to 15 kilometers deep, half of which is water. So there is a real difference between ocean basins and continental caps. The average density of the rock from the bottom of the ocean to the center of the earth is slightly higher than the average density of the rock from the same distance under a continent to the center of the earth. That is why the continent sticks up.

THICKNESS OF CRUST

Under the Tuamotu Islands, although surrounded by shallow water all around, it was a typical ocean structure, only about 6 kilometers thickness of crust beneath the water. Under the Easter Island rise it was 4 kilometers thick. This is the thinnest that they have found from the bottom of the water to the high-speed rocks of the mantle.

Dr. REVELLE. That was actually east of the rise.

Dr. TUVE. It wasn't on it? It was east?

Dr. REVELLE. It was in the basin east of the rise.

Dr. TUVE. That makes more sense.

Dr. REVELLE. The rise itself was a little bit thicker.

Dr. TUVE. That is about as thin as Dr. Raitt has ever found in the Pacific, whereas under the Nasca Ridge toward Nasca, Peru, which sticks out at right angles to the continent, it is about 15 kilometers.

Dr. REVELLE. That is the whole mountain range I was talking about.

Dr. TUVE. This is the mountain where they are making the heat measurements. All these things are tied together.

Dr. REVELLE. The interesting thing is that also you get just about the same thickness of the crust under the trench as you do in the deep sea.

Dr. TUVE. He got a measurement in the trench?

Dr. REVELLE. Yes, half a dozen measurements in the trench.

Dr. TUVE. That is no thicker and no thinner?

Dr. REVELLE. A little bit thicker but not very much thicker.

Dr. TUVE. Essentially it is as though it had been buckled down.

Dr. REVELLE. That is right.

Dr. TUVE. Of course, it is a possibility that there are some stresses, we don't know whether tension or compression.

Mr. THOMAS. You used the word "floating" a while ago, and you said you did not know what it was floating on. What do you mean by the word "floating" there?

Dr. TUVE. It means that essentially it is not held up as, for example, when I lean on the table my weight is carried by this table acting as a beam.

Mr. THOMAS. Do you mean you have a mass sticking up whose density is less than the density of the substance beneath it?

Dr. TUVE. Exactly.

Dr. REVELLE. Very much like slag in a steel furnace floating on the iron.

Mr. THOMAS. So when you say you are measuring density against density——

Dr. TUVE. What I mean is, if you take a gravity meter around this ball, it will read about the same at the same height every place. Actually it is very well adjusted. There are local dimples in an attraction, usually due to buried heavy rock, where there has been a flow of heavy basalt, for example.

HEAT FLOW AND CRUSTAL STRUCTURE

Mr. THOMAS. What about the measurement of heat in the mass of less density and in the mass of greater density that Dr. Revelle was measuring last summer down in that trough?

Dr. REVELLE. I think the easiest way to describe the floating, to give you a picture of it——

Mr. THOMAS. We know it is floating, but he gave 300 calories per square centimeter. How does this area compare with the area that you measured, where the density is much greater?

Dr. REVELLE. We are talking about the same area. The area with the high heat flow looks like a typical oceanic area. It is fairly shallow. It tends to be pushed up just as the trench tends to be pulled down. This is why Merle Tuve is saying that maybe there are differences in the mantle beneath the fold under the ridge and elsewhere.

Mr. THOMAS. Is this the 300-calorie area or the 10-calorie area?

Dr. REVELLE. The trench area is the area which is 10 calories per square centimeter per year. There you find a fairly shallow Moho, and you also find a fairly shallow Moho under the 300-calorie area. One is pushed up and one is pulled down. We know that in the trench area you have a very great departure from this floating situation that Merle is talking about. We know that there the trench is actually being pulled down by some force which is working against gravity. We need to make measurements of gravity on the Easter Island rise and see whether in fact it is being pushed up against the force of gravity where you get an excess of gravity here.

INFLUENCE OF LAVA

Dr. TUVE. I think Mr. Thomas might be interested in your remark before the Academy. Of course, part of the heat measurements may be the result of a very extensive lava flow which may have happened in the last 30,000 years or 50,000 years. It is still cooling, but still more heat is coming out of there than from the normal place.

Dr. REVELLE. It could be sometime within the last million years.

Dr. TUVE. Yes. In the State of Oregon and all the John Day Basin up there in Idaho, there was an enormous outflow of basalt many tens of millions of years ago. Beneath the Pacific it could be that there have been very large subocean flows of lava, perhaps even shielded by a couple of miles of sediment, the lava spreading

out in sheets beneath that. It would take that a very long time to cool, which again would affect the heat measurements.

GEOGRAPHY IN THE MANTLE

I do not want to confuse the question of density, the lighter and the heavier materials. The questions are really quite simple. We would like to know, speaking again from the seismologist's standpoint, whether these differences in density are pretty much limited to the crustal rocks which have been undergoing volcanism and weathering, exposure to water, air, and so on, for the past couple of billion years, or whether there are differences in density also down in these mantle rocks. It is too difficult to drill the mantle in many places, whereas we can make the gravity measurements very quickly.

Dr. REVELLE. I think we have to drill to it.

Dr. TUVE. We should drill in more than one place. If we find geography in the mantle as in the crust, then it is important to know this. We want to settle the question of whether the mantle is uniform or whether it is varied.

I am growing in the conviction that the mantle has variations in it, which is not in disagreement but simply a different interpretation of all the classical statements.

This is the kind of thing the seismologists have been doing.

STRAIN MEASUREMENT

Another thing we have been doing, and having a lot of fun, is to visit the two tunnels in South America where Dr. Benioff's seismometer has been installed. One of the things our panel picked up and fostered was to get some more of these instruments installed in the mountains. It may take 50 years for them to pay off. Meanwhile, they are the best for measuring earthquakes. It is a long quartz rod or pipe, about 2 inches in diameter, and each of them is installed in a tunnel which is dug at right angles in the mountain. There are two of these rods at right angles to each other. Essentially they measure the squeeze of the mountain. When an earthquake comes along, the rock squeezes and stretches, squeezes and stretches. That is what an earthquake wave, of course, really is. This measures it directly. You can see it with a microscope. Actually, it is done by recording instruments.

Those 2 have been installed, 1 in Santiago and the other up near Lima. There is a third one in California. They are installed in such a way that long-time changes extending over 30 years or 50 years will also be measured, because they are bolted to the rock and they stay there. The quartz stays the same length. It is very carefully assembled to make sure that nothing can change the length. They will measure the extent to which these rocks move under slow compression. When the compressions are released you have an earthquake, of course.

Those are two of the things which have been installed during the geophysical year for future interest.

EARTH TIDES

I might say one of the other things that we fostered was the business of earth tides. I forgot to look at the tide tables this morning. Actually it is out of phase with our water tides, anyway. This table goes up and down about 8 inches twice every day with respect to the center of the earth. We measured them for some years in Chevy Chase until I got tired of measuring them and shut off the instrument. They are quite regular.

The funny thing is, however, in Dr. Schlichter's laboratory, Dr. Pettit made an instrument about 10 times more sensitive, so point by point he would know that ours would fluctuate around a lot more but the average for the weeks was pretty good. Several years ago he made a gravity meter which was sensitive to thousandths of a milligal instead of hundredths of a milligal. He plotted the earth's tides very regularly. As you plotted it out it corresponded very exactly with the water tides that you could calculate if you took the earth and calculated it out, very nicely for Los Angeles where he was measuring. The only trouble is that he was about 6½ hours late. Nobody knows why. He took the instrument to Lawrence, Kans., and made measurements, and to Austin, Tex., and made measurements. He was out in Hawaii when the IGY came up, and he said this is something we want to foster. We have two of those instruments, and they are being carried around the world.

I neglected to say in Austin, Tex., it was exactly in phase with the tides; on the west coast, 4 hours out of phase. So he is carrying these measurements on around in Hawaii, Japan, the Mediterranean, and 2 or 3 other places in the world, to find this phase angle in the tides which gives a clue to the rigidity beneath the oceans and beneath the continents.

This is the kind of measurement that the gravity and seismology panel has been concerned with.

GEODETIC MEASUREMENTS

The other kind of thing we have been doing relates to exact position on the earth. The IGY originally was set up for synoptic activities. In other words, where it was very important for me in one place on the earth to measure at the same time somebody else measured the same thing at some other place on the earth. There was nothing very synoptic about the position of a continent. The continents stay there at least more than a year. But it is the kind of thing which does call for international collaboration and international interest. The astronomers got together. It happens one of the best systems of modern scientific measurement was developed in the past half dozen years or so by Dr. Markowitz at our own Naval Observatory here in Washington. This is the moon camera. This was picked up as a thing that really should be fostered and spread around the world. So 20 moon cameras were made. Many parts were made right here at the Naval Observatory. They have been spread around the world.

By these they take precisely timed photographs of the moon. The instant at which a star appears over the rim of the moon or disappears behind the moon depends on the exact position of the moon

craters. It can vary by a small time, depending on whether there was a bump or a hollow on the moon at that point.

The moon oscillates a little bit and the stars are in different positions, and this brought about irregularities to measurements. This was canceled out by the moon cameras.

Mr. THOMAS. What is Dr. Fuller doing there about getting to X place about 5,000 miles away if you can't measure it correctly?

Dr. TUVE. We will get it close enough.

Mr. THOMAS. He has nothing to worry about in that regard, then?

Dr. TUVE. No. It is interesting to know whether the skin of the earth is so tight that the continents can or cannot move. This has been going on since the 1880's, the Wegener hypothesis. One of the things we can lay down, if this is the golden age of America, is to manage to have the data written down on rock or something in the right place, in lead plates, perhaps, so 500 years from now somebody will make more accurate measurements and that knowledge will be handed down and communicated. Perhaps it is our duty to the future just as we have had advantages from the records of the ancients.

There have been two of these things; not only moon cameras, but the astrolabes. We carried astrolabes to the Andes and, fortunately, didn't have to use them much.

This is a complicated gadget for finding exactly the instant that the stars pass the meridian, one star after another, in order to find precisely where you are. The astrolabes measure within about 10 or 15 feet of the position of the observer, which is very nice. All we wanted was to get within a quarter of a mile.

Position measurements between longitude and latitude will be one of the things we will have to hand down to future generations.

This has been the kind of a thing that many people in the United States would be glad simply to know about, to know that they share in these explorations just for the joy of learning things.

Mr. THOMAS. A fine statement.

CAUSES OF EARTHQUAKES

Mr. YATES. How long will Dr. Revelle's laboratories be with us, in view of the number of earthquakes that have been taking place in California? Why do these earthquakes occur?

Dr. TUVE. I think they will be with us a long time. The people in the State of California will appreciate how important this kind of contribution is to the general cultural scene. That is one of the things that the IGY represents; namely, it is an effort of the people of the whole country. If you look back to——

Mr. YATES. I am thinking more of the scientific aspects. What makes the earthquakes take place in California?

Dr. TUVE. We ignore the California earthquakes. They are teeny-weeny things. There was a rather large one just after we left.

Mr. YATES. What causes them?

Dr. TUVE. Probably a release of pressure, and then you get expansion.

Dr. REVELLE. The earth is not uniformly weak, nor uniformly strong. There are cracks in it. The motion takes place, mostly, along

the cracks. There is a big crack going right through California, a fault which goes out to sea and down to the Gulf of California. There is a lot of motion that takes place there. Actually——

Mr. YATES. You need a welding job, then.

Dr. REVELLE. If you had a welding job there it would crack somewhere else. Actually, all the way around the Pacific you get earthquakes, and they are associated with the trenches I talked about. There is a ring of volcanoes all the way around it, and earthquakes take place all the way around that.

IGY PROGRAMS IN SOLAR ACTIVITY, IONOSPHERIC PHYSICS, AND WORLD DAYS AND COMMUNICATIONS

Dr. KAPLAN. The next speaker is Vice Chairman of the United States National Committee for the IGY and the Chief of the Sun-Earth Relationship Section, Central Radio Propagation Laboratory, National Bureau of Standards.

I might, at this point, Mr. Chairman, also point out that the variety of the speakers indicates the wide spectrum of cooperation represented in these universities, Government laboratories, industry, in the case of Dr. Porter, and so on.

Mr. Shapley is a very busy man in the IGY, and he will start the report on the physics of the upper atmosphere, rockets, and satellites, by describing the progress in our programs in solar activity and ionospheric physics.

Mr. THOMAS. Fine.

Mr. SHAPLEY. Now we get our feet off the ground. I think we will find there have been interesting developments in the IGY program in the high atmosphere, just as there have been in the earth, in its oceans and the lower atmosphere. Because of the time limitation, I shall briefly supplement my written testimony.

(The statement referred to follows:)

IGY PROGRAMS IN SOLAR ACTIVITY, IONOSPHERIC PHYSICS, AND WORLD DAYS AND COMMUNICATIONS

I am very honored to have this opportunity to appear before this committee to discuss with you the IGY programs in solar activity, ionospheric physics, and world days and communications. These programs are all related to the study of the physics of the high atmosphere, with particular emphasis on electrical effects stemming from incoming solar radiation such as ultraviolet and X-rays.

I. SOLAR ACTIVITY

The earth without the sun would be a lifeless planet adrift in space. As we are all aware, the sun is the basic source of practically all of our energy supplies, ranging from the direct, visible radiation of sunlight to unseen and difficult-to-detect radiations which are entrapped high in the atmosphere above us. Without the continued flow of energy from the sun, the earth would be dark—dark almost beyond imagination—for all of the hours of the days, deprived of sunlight, moonlight, and the additional contributions of sunlight which reach us after reflection from the planets. Only the faint light of the distant stars would remain to interrupt the total darkness.

To turn off (or, indeed, to turn up) the sun would produce dramatic and catastrophic effects upon life and the geophysics of the earth. It is only natural, then, that scientists would pursue the questions of what would happen if the sun should dim or brighten just a little.

Many of the geophysical investigations underway during the IGY are directed precisely toward measuring the small and large effects caused by the changing sun. The visible radiation which most of us consider as sunlight probably does

not vary by more than a few percent over long periods of time, according to investigations by the Smithsonian Institution extending over 5 decades. But the energies of X-rays from the sun, cosmic rays from the sun, radio emission from the sun, streams of ions from the sun, and ultraviolet radiation from the sun probably oscillate by large factors over periods as short as a minute and as long as many years. Many scientists believe these variations produce great variations in conditions in the earth's atmosphere, for instance. The purpose of the solar activity program of the IGY is to detect changes in the sun during this 18-month period so that these changes may be related to geophysical events. Also it is possible, to a modest extent, to outguess the sun and predict when great increases in solar activity are likely to take place. When this is possible, other IGY programs in geophysics may be especially alerted for concentrated observations during these periods.

The sun is also most important to study in itself, as it is the nearest star to the earth, and the only star which can be studied in any detail at all. What we learn about this nearest star has applications to the unfathomed depths of space.

Sunspot cycle.—The IGY period was chosen to coincide with the maximum of this solar cycle, and in fact, this is the most active cycle yet observed since 1755, when systematic solar observations began. Galileo, over 300 years ago, first discovered disturbances on the sun, the sunspots, and made maps of sunspots which are respectable even by today's improved quality standards. It was soon noticed, after systematic mapping of sunspots was started, that the number of sunspots waxed and waned in a pattern with a cycle of about 11 years. It was not until recent times, however, that any terrestrial consequence of this sunspot cycle was discovered.

Shortly after the first polar year, 1882–83, the connection between sunspot activity and auroral displays and geomagnetic storms was suspected. In the 20th century, after the discovery of radio wave propagation and the probing of the electrified layers of the ionosphere with radar techniques, scientists found that ionospheric disturbances were also related to sunspot activity. Astronomers, in the meantime, had developed instruments which could artificially eclipse the sun, allowing the study of the light from beyond the sun's edge, in the so-called chromosphere and corona. It was found that giant surges of material often shoot out of the sun, particularly during high sunspot activity.

We know today that in some as yet unexplained way, storminess of the sun's surface and ejection of solar material in flares and prominences are related to sunspots. We do not know very much yet about sunspots, however, except that as they increase in number to maximum every 11 or so years, the number of solar flares and other giant disturbances increase, and that these events are manifested on the earth by auroral displays, ionospheric blackouts, magnetic storms, and sometimes cosmic ray changes of great amplitude; it has also been suggested that certain kinds of weather effects are associated with the solar cycle, but this has not been definitely established.

Solar patrols

There are two aspects of the IGY solar activity program. The first is a patrol and warning system for other IGY researches, the second a research function itself. The warning system network of observing stations maintains a constant patrol of the sun using visual, optical, photographic, photometric, and radio techniques. The IGY was chosen to take place during a sunspot maximum so that the variations of electrical conditions of the high atmosphere, most of which are related to solar activity, might advantageously be studied. Many kinds of disturbances in the high atmosphere hinge on solar storms which produce bursts of ultraviolet, X-ray, and particle radiation. The solar warning system was developed to give advance notice of the likely occurrence of such events. The solar observatories provide information to the IGY World Warning Agency, operated by the United States, which every day examines solar reports and decides whether or not an important solar disturbance with associated terrestrial effects is likely to occur; in turn the World Warning Agency issues a call for increased observations in ionospheric physics, aurora, geomagnetism, cosmic rays, and solar activity whenever the probability is high for a major solar event with consequent terrestrial effects.

Optical patrol.—Of the over 100 solar patrols operated around the world by 33 countries, 14 are operated in the United States. A very strategic new location was established in Hawaii by the University of Hawaii. Optical and radio observations in Hawaii have closed the serious observing gap in the Pacific and now the sun is under watch every minute of every day throughout the IGY,

weather permitting. And there are enough stations around the world so that at one or another the weather almost always permits.

By observing the sun through special filters which limit transmission to the light of certain radiations of hydrogen or calcium, astronomers look for the giant eruptions or flares on the sun which are responsible for radio blackouts, auroras, and magnetic storms. Very narrow band filters are used, since the flares would otherwise be invisible against the bright surface of the sun. Many observatories take pictures of the sun every minute or less, and all these photographs are coordinated by international IGY agreement.

After the IGY is over we will be able to compose a time-lapse study of the solar disk, photographed in the light of gaseous clouds of hydrogen or calcium, for a complete 18-month period. These photographs, with all other coordinated observations will provide solar astronomers with the most detailed history of the sun ever compiled, by design during the maximum period of solar activity and by fortunate coincidence in the greatest cycle ever observed.

Radio patrols.—The sun emits radio frequency energy which can be readily detected by large parabolic antennas. Special stations were set up at an internationally agreed-upon frequency, about 200 megacycles, to supplement the optical patrol stations. The radio patrol, of course, is not hampered by poor seeing conditions and hence fewer stations than for optical observations are required to give good coverage. Along with the optical station in Hawaii, a radio telescope monitors the sun, completing a gap in coverage in the Pacific.

Indirect patrols.—The solar events are observed indirectly by monitoring noise radiated by distant electrical discharges in thunderstorms and the transmission through the atmosphere of galactic and cosmic noise. When a flare occurs galactic and cosmic noise decreases because of increased absorption in the ionosphere, but signals from distant thunderstorms increase because increased ionization in the low ionosphere makes it a better reflector for these low frequency (27 kilocycles) signals. Instruments were developed at High Altitude Observatory to monitor cosmic noise at 18 megacycles and thunderstorm signals at 27 kilocycles, and are now an important part of the flare-patrol program.

Special research observations

The patrol work provides very important data for the solar astronomers in their effort to learn more about the solar processes responsible for ultraviolet and X-ray emission, bursts of radio emission, and ejection of particles. For example, it has been found at High Altitude Observatory that the instrument which monitors the cosmic noise at 18 megacycles is sufficiently stable over long periods of time to permit quantitative measurements of the absolute change in transmission through the ionosphere. From this, High Altitude Observatory scientists can calculate the amount of the ionizing flare radiation which gives important data on the energy released in flares. In addition several new or special instruments have been built for intensified IGY research observations in an effort to study directly some of the basic processes in the solar chromosphere, corona and surface eruptions such as flares.

K-coronameter.—One of these instruments is the K-coronameter which is a special device for measuring and recording the brightness of light scattered by free electrons in the electron, or K, corona of the sun. The K-corona is much fainter than the emission corona where light is produced by the ordinary atomic transitions.

The new K-coronameter, to date, has obtained successful observations of previously unobserved details of the sun on over 40 days during the IGY. For this instrument to succeed, the sky must be extraordinarily clear, even for the special high-altitude station in the Colorado Rockies where it is operated. These 40 days of observations have provided us with a study of the variations of the depth of the layers of the corona where fantastically high temperatures reign, and where a good part of the sun's radar-frequency radio waves originate. It is quite possible that, coupled with other observations from IGY stations, we will gain new knowledge about how auroras, magnetic storms, and polar region communications fadeouts occur.

Profile spectograph.—Another instrument that had been put into operation obtains the profile of spectrum lines in a flare, from which the conditions of temperature and gaseous pressures can be determined. The flares so studied are perhaps the most important of all solar sources of terrestrial disturbances. When a large flare occurs on the sun there is an instantaneous total radio blackout on all long distance shortwave radio transmissions. But it is very difficult to know just what happens on the sun during a flare. We know that temperatures rise, perhaps by over a million degrees, in just a minute or two.

But the brilliance of the sun's normal light makes it most difficult for the astronomer to separate out the spectrum of the flare for study. The new instruments greatly facilitate this. If during the IGY a few successful spectra are obtained for major flares, all efforts will be justified. But it will require a big flare, just at the edge of the sun, and a very skilled and alert observer, because things happen fast. A number of United States stations and stations in other countries are engaged in the effort.

Coronagraph.—Special instruments are also in use to photograph the chromosphere of the sun, a shell of very hot incandescent gas just above the sun's surface, and the corona, an envelope of gas that may extend all the way to the earth. The chromosphere and corona are invisible except when an eclipse shuts off the light of the disk, or when the sun is artificially eclipsed in a special telescope called the coronagraph. Using the coronagraph, scientists are able also to photograph solar flares at the edge of the sun; these flares sometimes shoot out into space for several hundred thousand miles at very high speed.

Solar magnetograph.—At Mount Wilson Observatory in California, measurements are being made of the magnetic field of the sun at its surface. It has already been found that magnetic fields at the sun's surface may be very high, as much as 8,000 times that of the earth's field at the equator. These magnetic fields are thought to play a very important role in disturbances and storms on the sun's surface as well as in sunspots.

Scientists at Mount Wilson Observatory report that the south magnetic pole of the sun has reversed its polarity and the intensity at the North Pole has decreased. This significant change of intensity and reversal of polarity at the South Pole is delayed in phase some 3 years with respect to minimum sunspot count. The variations of the sun's field, Mount Wilson scientists believe, probably reflect large-scale patterns of circulation related to the 22-year solar magnetic cycle; they seem to be closely related to various solar-terrestrial phenomena.

Radio techniques.—Highly directional radio equipment have been developed which operate as telecopes examining and recording radio emissions from the sun. By very rapidly and automatically tuning the receiver, it is possible to follow the passages of globs of ionized particles from the disk of the sun out into space, confirming observations made in other ways that the outer extremities of the sun are in a state of violent turmoil.

Rocket observations.—Rockets can be flown into the higher atmosphere during solar disturbances to observe directly, without the screening effect of the lower atmosphere, the incoming solar radiation responsible for the terrestrial disturbances.

During periods of maximum solar activity radio communications are often interrupted by "fadeouts" or "blackouts," particularly after the occurrence of a flare on the sun. On these occasions pulses transmitted to the ionosphere by ionospheric sounders are not reflected as usual but are absorbed. It had long been thought, but not heretofore conclusively established, that this absorption must be caused by increased ionization in the lower atmosphere. On July 4, 1957, radio signals received from a rocket fired up through the ionosphere demonstrated the presence of an additional layer of ionization extending for about 12 miles below the normal lowest point. Even more remarkably, the rocket data showed that the normal ion distribution throughout the ionosphere above the D, or lowest, layer, seemed to remain undisturbed during the blackout. In another recent IGY rocket experiment, it was ascertained that the additional electron layer was caused by solar X-ray emission associated with the occurrence of solar flares. Other examples of rocket firings are discussed in the section on the IGY rocket program.

Total eclipse.—On October 12, 1958, a total eclipse of the sun will occur, which will be visible from certain islands in the Central Pacific. Natural solar eclipse observations remain the only way to observe, with greatest detail, the very inner regions of the sun's corona and chromosphere. A special expedition is being arranged with the United States Navy supplying a ship and other logistic support. Several institutions, including the National Bureau of Standards, High Altitude Observatory, the Sacramento Peak Observatory, the University of Wisconsin, the California Academy of Sciences, and the Naval Research Laboratory are preparing special observing equipment. The latter institution which has pioneered the use of small solid-fuel rockets fired on notice of solar disturbances, will attempt for the first time a series of closely timed rocket firings carrying equipment to detect energetic solar radiation, to see how this radiation at

the top of the atmosphere changes as the moon occults the disk of the sun. This will be one of the most completely equipped eclipse expeditions in the history of solar observations, with the unique rocket methods in addition. Also, the expedition observations will be greatly enhanced by the intensified solar observations during the IGY.

II. IONOSPHERIC PHYSICS

The planned program for studying, on a global scale, the electrified portion of the high atmosphere—the ionosphere—is well underway. 71 United States sponsored stations with various specialized equipment are in systematic operation as are a large fraction of the more than 175 stations sponsored by IGY committees of other countries. Data from these stations gathered throughout the world are flowing to the IGY world data centers according to the plan, and preliminary analyses have been started. It will take years, even decades, to study these data from all of the aspects now known to be of interest for improving our understanding of the production, maintenance and dynamics of the ionosphere and, for example, its efficient use in long-range radio communications.

Vertical soundings.—Early analyses of the radar-like probings of the ionosphere 50 to 200 miles overhead, at selected groups of stations, have thrown light on some problems but have also raised some new questions. Of particular interest has been the ionosphere over the polar caps, subjected to extended exposure to ionizing rays of sunlight during the long polar summer day and then screened from sunlight for several months during the polar night. If the first year's results from the Antarctic are representative, we can judge that the ionization reaches a saturation point during the long summer day amounting to about 450,000 electrons per cubic centimeter at the South Pole at this time in the solar activity cycle. This would support transpolar communications up to 22 megacycles. We also find that the upper or F-layer of the ionosphere persists throughout the polar night although the ordinary, rather uniform layer seems to break up into cloud formations. A typical density is 200,000 electrons per cubic centimeter which would support transpolar communication up to 14 megacycles if no ionospheric storm were in progress. As the data from the stations of many countries arrive through the international IGY channels, a study of the observations from the whole network of vertical souding stations has been started to see whether the electronic clouds observed at the Pole Station during the polar night drift in from the region of the sunlit Antarctic Circle, or whether a single cloud somehow persists over the pole throughout the winter. We do find a diurnal variation in the degree of ionization at the South Pole, even though the sun is always at a constant height above (or below) the horizon. This tells us that the earth effect on the ionosphere—probably an effect of the geomagnetic field—can amount to as much as 50 percent of the solar effect even in the absence of geomagnetic storms.

The comparison of the ionosphere in the North Polar regions with the observations made in Antarctica have shown many similarities and some differences. This comparison has provided strong evidence that the nonsolar variations in the F-layer are related to the inclination of the earth's magnetic field at the point of observation rather than to the component of the earth's field there having a form like that of a simple bar magnet. These IGY observations should result in significant changes in maps of radio frequency predictions for radio communications in both northern and southern latitudes.

During the first 11 months of the IGY there have been a number of ionospheric disturbances, which provide material for study of the storm processes and their relationship to simultaneous geomagnetic and auroral abnormalities and the preceding solar activity. The IGY inaugural storm—on July 1, 1957—is one of special interest as is the series of five overlapping disturbances in August and September. The storm of February 11 was most remarkable for its severe abrupt and large discontinuities and for the unusual accompanying auroral display. These studies will be historic because of the unprecedented number of stations throughout the world taking observations at the unusual frequency of 1 each 5 or 15 minutes. Full data are still being assembled for analysis, but spot checks indicate a number of unusual features including rare appearances of certain types of low-lying (65 mile) E-layer clouds at low latitudes.

The reduction of vertical echo-sounding data to actual electron densities as a function of altitude has been a difficult theoretical problem because the probing radio waves are slowed down and bent in a complicated way during the journey

to the ionosphere and back. When the IGY began, however, techniques had been developed which permitted this reduction to be carried out rapidly and with reliability using machine computers. Already it has been learned from these "true height" determinations for a selection of days and stations that the uppermost or F-layer of the ionosphere undergoes a pronounced pinching so that it changes from a very thick layer in the daytime to a very thin one at night. Under some conditions this pinching contributes to cause the maximum F-layer density to rise to a higher value in the course of a night. The pinching phenomenon had not been suspected before and its discovery will influence the construction of theories to explain F-region behavior.

Ionospheric scatter.—An important part of the United States ionospheric program is the observation of "backscatter" echoes at a network of 13 stations. These echoes result when radio waves incident obliquely on the ionosphere are reflected to earth farther along the transmission path, only to be scattered back again along the original path to the transmitter-receiver. New information has been discovered on large-scale traveling disturbances in the F-region and on the role of "tilted" ionospheric layers in propagating radio signals over long distances. It has proven possible to track the motion of F-region traveling disturbances over distances of more than 2,000 miles and to establish that the disturbances often extend to equivalent distances in directions perpendicular to that of the motion. They appear to be a kind of gigantic wave motion in the ionosphere.

It has been established through the study of scatter-sounding data that tilts in the F-layer can result in propagation of radio signals to great distances without intervening reflections at the earth's surface. The presence of a tilt or horizontal gradient in the ionosphere makes it possible to launch a radio wave in such a manner that it can travel by successive reflections at the "curved" F-layer until it strikes a tilt which returns it to earth. Propagation over distances in excess of 6,000 miles is commonly observed.

Other ionospheric scatter effects are being studied in South America under the United States program. Six circuits in which transmission is effected by ionospheric scatter of the obliquely incident 50 megacycle waves have been established to span the geomagnetic equator and provide east-west control data. The variability in daytime scattering along these paths has been found to correlate with the presence of the high-density electron concentrations in the E-region known as equatorial sporadic E. There is further correlation with intensity variations of the horizontal component of the earth's magnetic field. Since these are in turn associated with the ionospheric equatorial ion streams known as the equatorial electrojet, these propagation studies are helping to define the relation between equatorial sporadic E ionization and the equatorial electrojet. On the other hand, nighttime scatter signal seems to be correlated with the presence of disturbed conditions in the F-region observed as "equatorial spread F." The knowledge that the nighttime transmission scattering probably occurs at 80- to 125-mile levels provides evidence that the equatorial spread F effect itself arises in that altitude range.

In another IGY project signals scattered from sporadic E ionization are being measured for radio circuits in the Far East and in the Caribbean. An unusual high evening signal enhancement on the Far Eastern circuits was observed during the winter months. No similar enhancement was recorded in the Western Hemisphere, and the effect has not yet been explained. Many additional reports of transmissions by means of sporadic E, "single hop," and ionospheric forward scatter propagation are received from radio amateurs under a special IGY project established to collect and analyze their data. More than 500 individuals are supplying data; some 70 of them are living in foreign countries.

Whistlers and very low frequency phenomena.—New information about the farthest reaches of the atmosphere is being obtained from the study of "whistlers"—whistlelike sounds which can be detected at very low radio frequencies. These signals, originating in lightning flashes at the surface of the earth, swing out thousands of miles along the earth's lines of magnetic force before they return to the opposite polar hemisphere. Early IGY experiments demonstrated that the ion density along the whistler path at altitudes of as much as twice the earth's radius must be much greater than formerly anticipated. Indeed, there seems to be confirmation for the theory that the earth's atmosphere extends far beyond the level where it had been previously thought to "end" and that there may be a very tenuous atmosphere—the sun's corona—filling all the space between the earth and the sun.

The frequency of whistler occurrence seems to vary markedly from place to place. Ellsworth Station in the Antarctic is very active, as is Unalaska, Alaska. But somewhere between Frobisher (geographic latitude 63°) in northern Canada and Thule (latitude 77°) the whistler activity effectively disappears. On the other hand the Alaskan stations at College and Kotzebue which are at the same geomagnetic latitude, but differ in longitude by 15°, report good correlation of the whistlers received at the two stations. Nevertheless, the occurrence frequency of other very low frequency emissions (not whistlers) at College is twice that at Kotzebue. Although located in different hemispheres the stations at Wellington and Stanford are also situated at approximately the same geomagnetic latitude. Again, the whistler rate is comparable, but at Wellington the very low frequency emission occurrence is high, whereas at Stanford such emissions are identified infrequently.

Another new result concerns the correlation of whistlers recorded at Stanford and Seattle. On one occasion the same whistler group was recorded at the two locations. At Stanford the first component of the whistler was extremely well defined and extended upward to 35 kilocycles. At Seattle, however, no trace of the first component could be found, but later traces in the group were identical with those at Stanford.

Sometimes whistlers are observed in which the tone both rises and falls in frequency simultaneously. The frequency from which these components develop is called the nose frequency, and the whistler a nose whistler. The shape of nose whistlers is related to the intensity of the earth's field along the whistler path and gives information on the distribution of ionization as well. Two such whistlers have been observed for the first time at Stanford. The nose frequencies were 10 and 16 kilocycles, much below the expected value of about 45 kilocycles. Unusually low nose frequencies of 6 to 8 kilocycles have also been observed in Washington, D. C.

A single whistler has been recorded simultaneously at Stanford, Seattle, and Anchorage, in spite of the fact that the distance between Stanford and Anchorage is 4,000 miles. The records show similar frequency characteristics which are nevertheless not identical at the three locations.

Other ionospheric experiments.—Naturally occurring radio noise—static—is being observed and recorded on eight different frequencies at locations distributed widely over the earth. Information has been gained in this IGY program which will result in improved accuracy of predictions of radio noise for the United States at certain seasons. In particular, recorded noise in the early afternoon in summer is much higher than predicted, and the observed diurnal variation of noise at 20 megacycles is much different from the diurnal curve which had been predicted.

The scintillations of radio stars, as observed from three receivers spaced a mile or two apart on the ground, provide a means of studying ionospheric movements. The United States-IGY station has been in full operation, but because the data are not useful until subjected to lengthy statistical analysis general findings have not yet been reported. Similarly, a complete set of tabulated data has been obtained from a special station established to study ionospheric absorption by means of the attenuation of pulse echoes returned from the ionosphere. The ionospheric program also includes cooperative investigation with the auroral scientists of ionospheric absorption by observation of galactic radio noise received through the ionosphere. Some of the early findings are presented in the report on auroral studies.

A whole new technique for studying the ionosphere has been opened up with the availability of beacon radio transmitters carried in the IGY earth satellites. Several United States groups are taking advantage of the availability of a radio source above the ionospheric layers to measure ionospheric reflection and turbulence under various conditions, and, by indirect methods, to learn about the top side of the F-layer. Some valuable very long-distance radio propagation measurements are also being carried out. One puzzling early result is the discovery of radio signals apparently coming from a point antipodal to the actual satellite. This antipodal effect—or ghost satellite—has not been explained. Studies of these and other recent observations are still in progress.

III. WORLD DAYS AND COMMUNICATIONS

World days

The synoptic objectives of the IGY program require that simultaneous observations be made in most of the disciplines throughout the world. Regular schedules to achieve this have been arranged. During some periods, however, an intensi-

fication in the observational programs is desirable and for this reason the world days program was established. There are three classes of special days or periods during which special experiments or intensified observations will be undertaken: Regular world days, world meteorological intervals, and special world intervals.

Preselected world days.—World meteorological intervals (WMI) are series of 10 consecutive days each in June, September, December, and March. They coincide exactly with two pentades of the World Meteorological Organization and always include either a solstice or equinox, periods during which intensified meteorological observatons are most desirable, at least on a predictable basis.

Regular world days (RWD) are 3 or 4 days each month that are selected in advance. Two are consecutive days at the time of new moon; the others are at times of unusual meteor showers (Geminid, Perseid, Taurid, etc.), or near one of the lunar quarter phases. The RWD will also include the days of solar eclipse, with adjacent days for control purposes. For those types of observations which are insensitive to lunar phase or meteoric effects and for those observations which cannot be carried out continuously throughout the IGY period, the RWD should constitute a representative sample of the IGY period and the resulting concentration of effort should be useful in the interpretation of results in all disciplines. IGY nations with rocket programs have agreed to concentrate efforts on coordinated rocket firings on 1 of the world days, June 18, which occurs during a WMI.

Special world days.—Special world intervals (SWI) are designated on a day-to-day basis by the IGY World Warning Agency in the United States, acting with the advice of forecasting centers throughout the world. A period of alert will be declared whenever solar activity is unusually high and significant geomagnetic, auroral, ionospheric, or cosmic ray effects are probable. During the period of alert, an SWI may be declared (at 1600 universal time to commence at 0001 universal time the following day) whenever the probability is high that an outstanding geomagnetic storm, with associated effects in other disciplines, will begin within a few hours. The periods of alert and SWI will continue in effect until terminated by the World Warning Agency. An effort will be made to predict only the most outstanding disturbances in the designation of the SWI.

An example of the operation of the World Warning Agency occurred when a large solar flare, of importance 3, was reported by Krasnaya Pakhra Observatory, Moscow, U. S. S. R., as having begun at 0700 universal time June 28, 1957. Although this was the only report on the flare, its importance was such that the World Warning Agency declared a state of alert beginning at 1600 universal time the same day. This was followed, on June 29, by designation of an SWI commencing at 0001 universal time June 30. The SWI continued until 2359 universal time July 3, and the alert ended on July 6. A very large magnetic storm began about 0400 universal time June 30, lasting until about 0100 universal time July 2. During the magnetic storm great auroral activity was reported, and on July 1 communications were seriously disturbed; the quality figure for a 6-hour period that day was 1, the lowest in many years.

During alerts, volunteer aurora observers in low latitudes are notified to man their stations. These observers do not keep watch every night as auroras are very rare at low latitudes, and to make best use of their efforts they only observe during alerts, when solar conditions increase the probability of the occurrence of the great auroras. Auroral observers at high latitudes watch for auroral forms every clear night.

During SWI, ionospheric vertical incidence stations increase their soundings from about every 15 minutes to every 5 minutes. Auroral observers are alerted for increased instrumental observations, and visual observers intensify their watches. Particularly important is the observation of auroras in low latitudes following the greater magnetic storms, and observers in these areas are especially vigilant during the SWI. Some cosmic ray experiments—such as balloonborne experiments designed to detect cosmic rays of solar origin—are intensified for SWI. Rockets are held in readiness for firing during great magnetic storms, or as soon as possible after the onset of a flare. Solar astronomers also increase their observations during the SWI, particularly for experiments designed for better understanding of the solar eruption mechanisms.

IGY World Warning System

World Warning Agency.—A field station of the National Bureau of Standards, the North Atlantic Radio Warning Service (NARWS) located at Fort Belvoir, Va., about 20 miles from Washington, was designated by the CSAGI as the IGY World Warning Agency (WWA).

NARWS had had considerable previous experience forecasting ionospheric propagation conditions and was also engaged, with the cooperation of other such services throughout the world, in a study of the prediction of terrestrial solar disturbances.

Operation of WWA.—The WWA examines solar data each day and receives advice from forecasting centers throughout the world concerning the probable solar activity in the coming day. Each day, shortly before 11 a. m., eastern standard time, the WWA must make a decision as to the likelihood of imminent solar disturbances and related terrestrial effects, then issue the daily warning message at 1600 universal time (11 a. m. eastern standard time). Two kinds of messages are sent out on a day-to-day basis by the WWA: Alerts and SWI.

Alerts are called whenever solar activity is unusually high and significant geomagnetic, auroral, ionospheric, or cosmic ray effects are probable. The World Warning Agency utilizes certain criteria for judging the likelihood of impending solar-terrestrial effects, criteria that have been established empirically by past observations of solar astronomers and atmospheric physicists.

For example, an alert may be declared whenever an unusually active sunspot region is on the solar disk, particularly when it is near the east limb of the sun, 4 or 5 days before it rotates toward a position near the center of the disk. The degree of activity of a particular sunspot region is judged by several kinds of observations of the region from the time of its appearance on the limb and during its transit across the disk. At the limb, observation of the intensity of emission of the yellow coronal line, prominences of the "spray," "loop," and "surge" variety, and the occurrence of limb flares are especially important for judging potential activity of a region.

As the region passes on to the disk, the solar astronomers watch for occurrences of important flares in H-alpha or calcium light, unusual outbursts of radio frequency radiation, high radio flux levels or "noise storms," intense or unusually complex magnetic fields associated with the sunspots, and other similar phenomena. An alert is usually not declared unless the region has produced a flare of at least importance 2. (The importance factor ranges from subflares to importance 1, 2, and 3.)

During the period of an alert, an SWI may be declared, usually on 8 hours' notice, whenever the probability is high that an active region on the sun will produce an outstanding magnetic storm with associated effects. For example, if a solar flare of importance 3+ is reported by a solar observatory, it is then most likely that at the next opportunity an SWI will be announced by the World Warning Agency.

Dissemination of messages.—The WWA receives advice in the early part of the day (all times mentioned are universal time or 0° meridian time) from observatories located at Moscow, Paris, Nederhorst in the Netherlands, Kokubunji in Japan, Anchorage in Alaska, Prague, Sidney, and Boulder, Colo. At 1600 universal time each day a message is issued. Alerts commence upon receipt of the message and SWI, if called, commence at 0001 universal time the following day; alerts cease upon receipt of message, SWI at 2359 universal time the same day. The messages are as follows:

Alert starts X/1600Z.
Alert continues.
Alert finishes X/1600Z.
SWI starts Y/0001Z.
SWI continues.
SWI finishes X/2359Z and alert continues.
SWI finishes X/2359Z and alert finished X/1600Z.
No alert.
Alert starts X/1600Z and SWI starts Y/0001Z.

(X is the date of the message; Y is the following day's date.) These messages are sent to the regional warning centers and associate warning centers at:

Central Direction Netherlands P. T. T., The Hague, Netherlands.
Bureau Ionospherique Francais, Bagneux, France.
Fernmeldtechnisches Zentralamt, Darmstadt, Germany.
Institute of Terrestrial Magnetism, Ionosphere, and Radio propagation, Moscow, U. S. S. R.
Radio Research Laboratories, Kokubunji, Tokyo, Japan.
Ionospheric Station, Mount Stromlo, Canberra, Australia.
North Pacific Radio Warning Service, Anchorage, Alaska.
Williams Air Facility, McMurdo Sound, Antarctica.

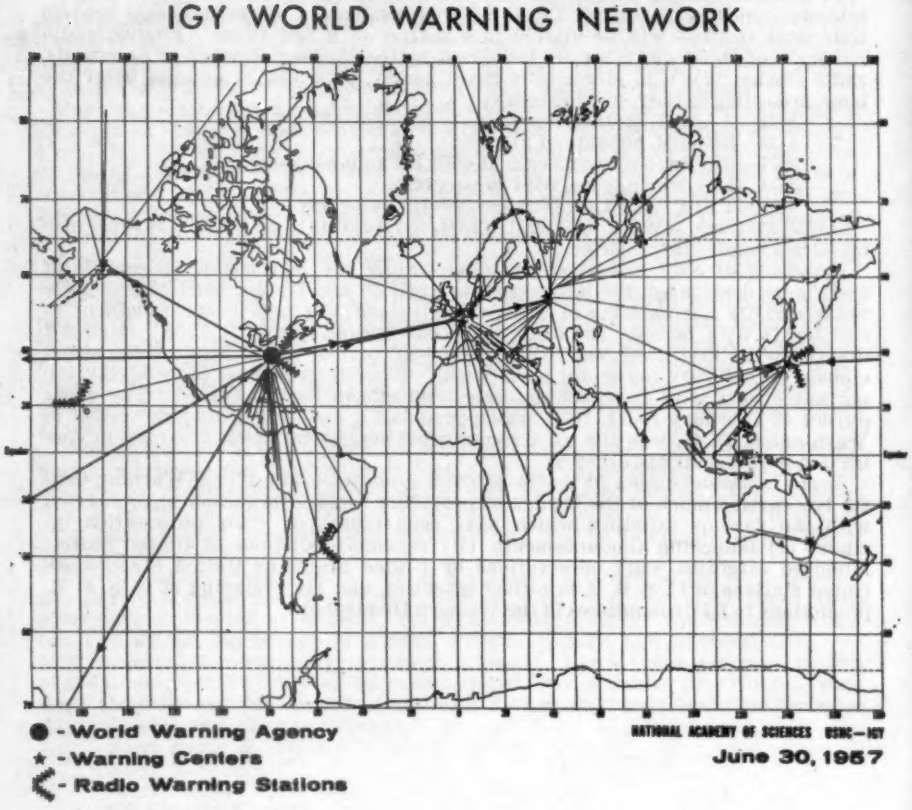
In addition, the messages are also fed into the international meteorological telecommunication circuits. Thus, rapid dissemination of the messages insures that most stations will be alerted in a matter of a few hours. Finally, radio messages of alerts and SWI are broadcast by the National Bureau of Standards' radio station WWV in Morse code twice hourly, at 4 and 34 minutes after the hour, according to the following codes:

AGI—AAAAA, state of alert.
AGI—EEEEE, no state of alert.
AGI—SSSSS, SWI will begin at 0001 UT following day.
AGI, three long dashes, SWI in progress.
AGI—TTTTT, SWI terminates 2359 UT same day.

Radio stations WWVH (Hawaii), LOL (Argentina), and JJY (Japan) also broadcast similar information.

Summary of SWI and alert messages.—Since the IGY began, 25 periods of alert were designated, the last occurring April 30 and lasting until May 5, 1958. Solar activity during some of these alert periods was sufficiently prominent to call for 11 SWI periods, the last SWI occurring on March 29, 1958. Earlier I described the first alert and SWI of the IGY period, which began most auspiciously with a very important solar event. Since then several more highly important events with far-reaching terrestrial effects have occurred. The great aurora of February 10–11, 1958, which produced a magnificent display visible in Washington, D. C., was the most recent great terrestrial event observed in connection with a solar disturbance.

Rapid communications for earth satellite program.—The World Warning Center has carried much of the burden of providing rapid information in connection with the various satellites which have been launched. This information includes (i) launching announcements, (ii) regular predictions of United States-launched satellites, (iii) observations by United States or United States-associated stations of U. S. S. R.-launched satellites, and (iv) relaying of U. S. S. R. predictions to IGY committees in the Western Hemisphere.


IGY WORLD WARNING NETWORK
● - World Warning Agency
★ - Warning Centers
- Radio Warning Stations
NATIONAL ACADEMY OF SCIENCES USNC—IGY
June 30, 1957

Final Calendar of Regular World Days (RWD) and World Meteorological Intervals (WMI) during the International Geophysical Year 1957-1958

(Adopted by CSAGI, September 1956 and edited by CSAGI SECRETARIAT - 3, AVENUE CIRCULAIRE, UCCLE-BELGIUM)

World Meteorological Interval: 20 21 22 23 24 25 26 27 28 29

Regular world day (11)
Regular world day at new moon (10)
Unusual meteoric activity 8 (but not world day)
Regular world day with unusual meteoric activity (17)
Day of total eclipse [12]

June 1957 (Advance Trial)

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	(27)	(28)	(29)
30						

July 1957

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
	1	2	3	(4)	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	(26)	(27)
28	29	30	31			

August 1957

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
				1	2	3
4	5	6	7	8	9	10
11	(12)	13	14	15	16	17
18	19	20	21	22	23	24
(25)	(26)	27	28	29	30	31

September 1957

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
(1)	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	(23)	(24)	25	26	27	28
29	(30)					

October 1957

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	(22)	[23]	(24)	25	26
27	28	29	30	31		

November 1957

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
					1	2
3	4	5	6	7	8	9
10	11	12	13	(14)	15	16
17	18	19	20	(21)	(22)	23
24	25	26	27	28	29	30

December 1957

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	(13)	14
15	(16)	17	18	19	20	(21)
(22)	23	24	25	26	27	28
29	30	31				

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January 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

February 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	

March 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
2	3	4	5	6	7	1/8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

April 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

May 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

June 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

July 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

August 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24/31	25	26	27	28	29	30

September 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

October 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

November 1958

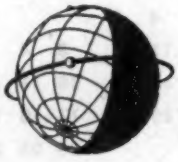
Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23/30	24	25	26	27	28	29

December 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

January 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31



SOLAR ACTIVITY PROGRAM

Mr. SHAPLEY. It is appropriate, I think, to start with discussion of the solar activity program because the sun is the source of almost all of the energy which gets into the earth from outer space and the variations in the sun's activity and the sun's radiations have important consequences in the upper atmosphere.

Dr. Kaplan mentioned at the very beginning that the IGY was selected to coincide with the time of the very highest solar activity.

PREDICTING THE SOLAR CYCLE

The solar activity—the number of sunspots, the number of solar outbursts, and things of that sort—waxes and wanes every 10 or 11 years. We were faced with the problem back in 1950, at the time of very early planning of the IGY, of picking the dates of very high solar activity. We had to decide whether to have the IGY in 1956, 1958, or 1960, and we had to predict the future course of solar activity.

The best estimate at that time gave about 1957 for the peak of solar activity.

I must confess that after the minimum in solar activity in 1954, the time when there were very few sunspots, very few interesting large-scale phenomena, we began to get a little bit worried. Was the prediction good? Immediately after the minimum of activity in 1954, the solar activity shot up very rapidly, and it reached an unprecedented high level by the end of 1956.

Would the peak be past before the IGY started? The sun did cooperate with the IGY just as 66 nations are cooperating with the IGY, and the solar activity continued to go up.

CURRENT CYCLE

I shall illustrate that by showing you a blown-up chart so you can see the time scale we are working on.

This is a chart of the sunspot index over a period of years, showing it goes up and down over a period of 11 years. There was a high point in solar activity in 1937 and another one in 1947. It was about at this point when we had to pick the date for the IGY.

As you see, the sun has cooperated with the IGY and it seems very certain now that the peak of solar activity for this hump will occur during the IGY period.

SUNSPOT INDEX

You can measure solar activity in quite a number of ways. The most common way is by a sunspot index, called the sunspot number. This fluctuates rather widely from day to day, from month to month, so we are in the habit of keeping track of the solar activity cycle by averages over a period of a year, and move the average forward as we go along.

According to this scheme we know now what the average level of solar activity was 6 months ago. At that time it was just about flat. The index was 199, and I think the peak will have been 6 months ago, November or December of 1957. However, it will take a few more months to see whether or not we have passed the peak.

IONOSPHERIC RADIO EFFECTS

Going in pace with the solar activity cycle there are quite a number of phenomena of the high atmosphere, important both for scientific studies and for practical purposes.

For instance, the reflectivity, the capability of the ionosphere to reflect radio waves in long-distance communication, marches along in step with the solar activity cycle.

The radio frequencies which you can use for, say transatlantic radiotelephone or radiotelegraph, are much higher at the maximum than they are at the minimum.

The prediction of the behavior of the ionosphere for use in communications is one of the important practical applications of studies of this sort and one in which the National Bureau of Standards has been engaged for many years.

SOLAR FLARES

In addition to this general level of solar activity, there occur short outbursts of enhanced solar radiation. We call them solar flares or solar outbursts. They are outbursts which perhaps last 15 minutes, perhaps 45 minutes, sometimes a couple of hours, when the sun's radiation is much increased in some parts of the sun's spectrum.

The whole area of the IGY researches concerning the high atmosphere is the effect of these bursts of solar radiation on the high atmosphere.

For this we want to know when these solar flares occur and what they are like and what their characteristics are. For this you have to keep watching the sun.

SOLAR PATROLS

One of the great successes of the IGY from my standpoint has been the fact that we have been able to arrange for a continuous watch on the sun for these solar flares with fairly standardized and specialized instruments. This has been a dream of astronomers and geophysicists for decades and decades, but it never has been accomplished until the IGY made it possible.

Concerning the effect of solar flares on the ionosphere, for example, it was relatively easy to have continuous radio probings of the ionosphere until something unusual happened. Most of the time we did not know whether or not this was a solar effect because there were too few solar observatories and the watch on the sun in this way was not complete.

During the IGY period there will be very few times when there will be doubt whether or not the sun was flaring at any given time.

These outbursts of solar radiation can be observed not only in optical wave lengths, as with special filters isolating the hydrogen emission

line in the sun's spectrum, but also by the use of radio telescopes observing the sunlight at radio frequencies.

The control of radio frequencies also has been complete during the IGY. It is not bothered by clouds and weather as much as the optical patrol, so you just have to have enough observatories on all sides.

In addition the sun has been watched and studied in other ways. We have watched the sunspots, which are most familiar to us, and they are being measured at several hundred places around the world during IGY. We hope to be able to get indices of solar activity over short periods of time from these sunspot observations. There are some other techniques that are being used.

I am glad to say that the solar patrols have been activated pretty much as planned, coverage is as good as we had hoped for, and even better. We are very close to a 24-hour patrol. This is one of the major contributions of the United States program to this coverage, installation of a new solar patrol station in the Hawaiian Islands. There is a wide gap between the west coast of the United States and Japan and Australia. Unless that gap is filled, the sun would have to go unwatched for several hours.

You will notice Hawaii has done a splendid job, starting pretty much from scratch, getting assistance from many places, and we have established solar patrols, both optical and radio.

In the same way, Cornell University has done an outstanding job in the radio phase of the work, and also Harvard University has done a splendid job, and the University of Michigan at its station in Ann Arbor has contributed importantly to this program.

Those I have mentioned in general are to be new stations established for the IGY program.

SOLAR RESEARCH EXPERIMENTS

There have been special solar experiments that are discussed in my written testimony. In general, this means that the solar astronomers are paying attention to the solar eruptions and what they are made of, how they operate in order to better understand the kinds of radiation throughout the spectrum that they send toward the earth. There are quite a number of experiments going on in this way.

OUTSTANDING SOLAR EVENTS

I thought you might be interested in knowing when the most outstanding days during the IGY happened so far as the sun is concerned.

Dr. Kaplan mentioned the way the sun cooperated with the beginning of the IGY by producing a brilliant flare on the eve of the IGY, and that there was a nice aurora, a magnetic storm on the very first day of the IGY.

Later on in the summer, in the period from about August 27 to September 30, solar activity was at a very, very high level. More than 20 flares or outbursts of the highest rank occurred during that time.

September 18 was probably the most outstanding day from this standpoint. We not only had solar activity, but there were several

examples of the probable effect of solar activity on the earth's atmosphere.

During this approximately 35-day period, there were 5 separate severe magnetic storms, and some of you may remember the auroras which were seen during last September. This will provide invaluable material for study of the IGY data.

Then on February 9 there was a flare which was an unusual flare. Its optical intensity in size was only moderate, but its radiation in radio frequency was both very strong and it did not behave the way bursts such as this usually do.

This phenomenon will bear close study because it was followed on February 11 by one of the sharpest magnetic storms ever recorded, with brilliant and colored aurora which I saw myself here in Washington from my apartment house, and it was seen much farther south, I believe down to Cuba. February 11 was the most active day thus far.

You can see that these solar eruptions come rather unexpectedly. Sometimes they can be anticipated a few days ahead of time. You can see that they will be valuable for the earthbound measurers in order to know when the best time is for observing.

COMMUNICATIONS AND SPECIAL WORLD INTERVALS

This brings me to communications, where by international arrangements through IGY channels there is a scheme for putting up a storm signal or an alert telling the IGY stations to be on guard for unusual things happening.

Then it seems most likely there will be very large magnetic storms, and there will then be a special interval invoked by the international IGY group. This is so that observers can concentrate their observations during times when their observations are apt to be most productive.

While all this is arranged, it is done through regional centers around the world. The way it is fixed up is that there are many experts, but some one group has to make a final decision, so it is arranged that the experts for estimating the degree of solar activity and its possible effects on the earth send in advice to the World Warning Agency. The experts in Czechoslovakia, Paris, Moscow, Tokyo, Sidney, Holland, and Germany all send their advice to the agency which is run by the National Bureau of Standards at one of their field stations down near Mount Vernon on the grounds of Fort Belvoir. These are the lads who have to make a final decision, particularly as to what solar activity will be in the coming hours.

I can advise that this day-to-day international cooperation in the IGY has been moving splendidly, by telegram, by radio, by broadcast, by telephone, and the data and advice flows around the world at the rate of 2 or 3 telegrams a day stating what the sun is doing, and so on. We have here the day-to-day cooperation of the IGY, and all groups are cooperating very well.

For instance, the decision to call a special interval at the very beginning of the IGY was largely based upon a solar flare which was seen at an observatory near Moscow.

Because of the time of the day and clouds it was not seen elsewhere. If it had not been for the IGY, the Bureau of Standards group here

in the United States, who also make communication forecasts which depend on these kinds of observations, would not have known they could anticipate a major magnetic storm and aurora display. It also works in the other direction. There are some flares which can be seen only from these longitudes, and it always is worth a great deal to have a scientific communication network, and this is the largest network ever assembled for these purposes.

We have looked at and said a few things about the sun, solar alerts and special intervals, and I should like now to review some of the high atmosphere experiments from the ionosphere. My colleagues will follow through with other aspects of this discussion.

PROBING THE IONOSPHERE

In the ionospheric program, the largest single experiment is the so-called radio probing of the ionosphere, a radar-type pulse experiment with the ionospheric layers as the targets. Ionospheric layers are some 65 to 200 miles high. The vertical soundings network was quite large before the IGY, but many important gaps in worldwide coverage have been plugged through the IGY program. All of the planned United States stations have been installed and are operating, from the Antarctic through cooperative stations in South America, a few on the east coast of North America, up at Thule, and up at the Ice Island station northwest of Thule. Considerable data are being accumulated and already some results are coming from that.

The vertical soundings experiment, this radar-type experiment, does not give you the actual height of the ionospheric layers. It gives you the radio height. The radio waves are slowed down and altered by passing through the ionosphere and they are affected by the free electrons which form the ionospheric layers.

TRUE IONOSPHERE HEIGHTS

One of the things that the IGY program really started and gave impetus to was a program where the radio heights of the ionosphere are converted by rather elaborate mathematical manipulations which require high-speed computers. They are converted to actual heights, whereas the equivalent heights, you might say, of the F layer, higher layer of the ionosphere, might be 250 kilometers the actual height would be down about 150 kilometers.

IONOSPHERIC MAPPING

There are important corrections for physical studies of the ionosphere. For the first time, we are able to do meteorological maps of the ionosphere. Dr. Wexler and his meteorological colleagues plot temperatures and pressures at constant altitude. Just as the oceanographers are borrowing from the meteorologists, so the ionosphere people are borrowing some of their maps from the meteorologists. Other experiments include scattering of radio waves by ionized clouds and especially interesting and productive as an experiment is one being done cooperatively with some South American groups down near the Equator. We find that the ionosphere is far from being symmetrical in these details about the geomagnetic equator. There

does seem to be a systematic shifting but the shifting is not constant from day to day. This will be important additional information to consider in connection with the electric currents that flow around in the atmosphere at the Equator.

MAGNETIC EQUATOR

Mr. YATES. When you talk about the geomagnetic equator, what do you mean?

Mr. SHAPLEY. The earth has a magnetic field, if you can visualize that as being made by a bar magnet. It is near the center of the earth with the North and South Poles, but if you extend the axis of the bar magnet up to the surface of the earth, that point would not be the same as the North Pole, the pole of rotation. It is tilted by about 12° from the pole of rotation.

Mr. YATES. This is almost perpendicular to the actual Equator except for that variation?

Mr. SHAPLEY. It is inclined about 12°.

Mr. YATES. This is called the geomagnetic equator?

Mr. SHAPLEY. Yes.

Dr. KAPLAN. Dr. Simpson will say more about that.

Mr. SHAPLEY. We used to call it that, but Dr. Simpson has done work in the IGY and just before which indicates that there may be several kinds of geomagnetic equators.

Mr. YATES. A destructive influence then?

Mr. SHAPLEY. Yes.

ANTARCTIC RESULTS

I might mention some of the results from the Antarctic. As to the ionosphere, electrification high in the atmosphere is produced by sunlight, by direct absorption of ultraviolet or even shorter wavelengths in the sun's radiation. One of the main reasons that we wanted to establish a geophysical station at the South Pole was to see what happened to the ionosphere when you did not see the sun for many months at a time during the long polar night and to study this in some detail.

Previously there had been only a few observations from airplanes near the poles. There is very little information on this subject.

As I think Dr. Wexler mentioned, there is an ionosphere over in the South Pole during the polar night. It is there. It is not as homogeneous and simple a layer as it is in places where there are both day and night alternately. It seems broken up into clouds and we are still investigating where these clouds come from.

Dr. TUVE. I have noticed that in the records.

Mr. SHAPLEY. There is the so-called abnormal E layer. I was talking about the main layer, the F layer, the higher layer. It is there and it will be very interesting to see, when the IGY data come in, as they are beginning to do now, from stations all around the continent, to study them and to see whether the ionization that we see at the South Pole during the polar night, has moved in from the Arctic Circle region or whether the ionization that we observe was the remains of what was there during the long summer day. This is a question that will take a collection of all of these data to answer, and it is for questions such as this that the scheme for collecting IGY data

into data centers was evolved. Without the arrangements for interchanging IGY data, it would be almost a hopeless task to collect the data from so many countries and from so many stations for studies of this sort.

The South Pole observations showed that even under continuous sunlight, the F layer of the ionosphere did not get more and more ionized but it reached a saturation point.

Another feature of the South Pole Station, of course, will be that the sun will always be a constant angle above the horizon or below the horizon for 24 hours a day. The observers there do not know what kind of time to use for their observations. There is no noon nor midnight. They usually refer these observations to those zero points.

MAGNETIC FIELD AND IONOSPHERE VARIATIONS

In spite of the fact that the sun stays at the same height, either above or below the horizon, 24 hours a day, it gradually marches up or down in altitude; and in spite of that, the degree of ionization underwent a diurnal variation. Because of the unique location of the South Pole Stations, you could get a measure of the amount which the sun controls the ionosphere as contrasted to the degree to which the earth's magnetic field controls the ionosphere. It looks as if, at this time and place, the earth's magnetic field can be up to 50 percent of the contributor to the variations in the F layer of the ionosphere. These experiments have important implications as to the prediction of the ionosphere for radiation purposes.

IONOSPHERE RESEARCH WITH SATELLITES

Finally, I would like to mention as a topic a new field in ionospheric research that was opened up by the success of the IGY earth-satellite program. With earthbound techniques, with radio probing, and so forth, we can only see up to the reflecting level of the ionosphere. We do not know much about ionization, electrification of the atmosphere above that point, but with a beacon transmitter in the earth's satellites, then studies of this sort can be made and are, in fact, being made with some success. At the same time, other, similar studies are measuring the refraction of radio waves.

INTERNATIONAL ASPECTS

The fields that I have mentioned here, solar activity, communications, and program in ionospheric physics, are programs that I feel have required international cooperation on a current basis. In many cases they have required cooperation on a day-to-day basis and on an hourly basis. Experience so far has been one that is very satisfying and things are going well. The results of observations are already flowing toward the data centers and analyses are commencing, as I have mentioned.

I think that emphasis on observations during the IGY period will prove to be a success and there should be some very hopeful results as to the practical uses of the ionosphere in communications. As we advance toward, shall we say, the space age, and are concerned with

the effect of solar activity on the high atmosphere and vehicles moving in the high atmosphere, the outlook is hopeful.

Mr. THOMAS. Very fine; very fine.

Thank you so much.

Dr. Kaplan?

IGY PROGRAM IN COSMIC RAYS AND GEOMAGNETISM

Dr. KAPLAN. Our next speaker is Dr. Simpson, who is a member of the United States National Committee for the IGY, professor of physics at the University of Chicago, and one of the pioneers in the study of cosmic rays and their relation to geophysics. He is going to talk about cosmic rays and geomagnetism.

Mr. THOMAS. Come around, Doctor. We are delighted to have you. Your statement will be inserted in the record at this point.

(The statement follows:)

IGY PROGRAMS IN COSMIC RAYS AND GEOMAGNETISM

I am very pleased to have this opportunity to appear here and discuss with you the first fruits of the IGY programs in cosmic rays and geomagnetism. These studies are both concerned with the nature of the terrestrial response to solar events and with the conditions in the medium through which the earth moves.

I. COSMIC RAYS

Cosmic rays are electrically charged particles of exceedingly high energy that attain their high energy within our galaxy and bombard the earth from all directions. On rare occasions our sun also produces short bursts of charged particles with cosmic ray energy which reach the earth. The search for the sources of cosmic rays and for the mechanism by which they acquire energy of 100 million to 10 billion billion electron volts is one of the major problems in physics today. During the past several years it has also become clear, from research in the United States, that the intensity of the cosmic radiation reaching the earth undergoes large changes with time, and that these changes with time are associated with electromagnetic phenomena on the sun. These solar phenomena are most pronounced and important near the maximum of solar activity. Phenomena which produce large-scale changes in the cosmic ray intensity at the earth have become the central problem of intense interest, not only for understanding cosmic ray and solar effects, but also because the solution of this problem is leading scientists to the discovery of magnetic fields in interplanetary space and the explanation of many magnetic storm effects at the earth.

Thus, studies undertaken during the maximum of solar activity, and for a considerable period thereafter, are of paramount importance. The IGY was chosen to occur at solar maximum, and it is for this reason that there is extensive cosmic ray research in the IGY. During the IGY scientists of 31 nations are studying cosmic rays at 195 stations. There is international cooperation, especially for carrying out measurements with Canada, Sweden, Mexico, and Peru. Scientists are using neutron monitors, meson telescopes, ionization chambers, photonuclear emulsions, and other special detectors. Rockets, balloons, airplanes, and artificial satellites are the vehicles carrying these instruments to observe the cosmic radiation at the top of the atmosphere or beyond. The following is a brief summary of the major new observations obtained during the past year.

Changes of cosmic radiation with time

Continuously operating cosmic ray intensity monitors reveal that as of early 1958 the total cosmic ray intensity above the atmosphere at the earth had decreased to at least one-half the intensity which was present in 1954. High-altitude balloon flights show, in addition, that the cosmic rays of lower energy have practically disappeared in these intervening years. Thus, United States scientists, using a variety of techniques at mountain stations, and in balloons, and aircraft, find that the beam of cosmic ray particles coming principally from the galaxy and arriving at the earth has drastically changed between the mini-

mum of solar activity (1954) and the present solar maximum of 1957–58. For example, even the individual components of the cosmic radiation show similar changes with time. The primary alpha particle intensity measured with photonuclear emulsions shows a similar decrease of intensity between 1954 and 1957. From earlier work it is know that the cosmic ray intensity will again increase in the coming year since this change follows the 11-year solar activity cycle.

Intensity changes of much shorter duration may be of large magnitude. For example, a sharp intensity decrease of about 25 percent occurred in the cosmic radiation as a consequence of a dramatic solar event. Early in the morning of August 28, 1957, a large solar flare of outstanding importance was observed on the sun. The following day there occurred a magnetic storm of great intensity, producing large effects in the auroral zone. The continuously operating cosmic ray detector showed that the decrease at the top of the atmosphere should have been approximately 25 percent. Several balloon flights were undertaken during this period which not only observed changes of this magnitude, but also revealed, for the first time, that the proton and alpha particle fluxes did not follow each other as expected on the basis of current theories for explaining these large intensity variations. Moreover, during this event, it was found, for the first time, that X-rays were associated with the event and also with the auroral displays in the Arctic. This new effect is discussed in the following section.

Several investigations using balloon, aircraft, and earthbound detectors have demonstrated the existence of smaller and shorter time cosmic ray intensity fluctuations whose origin is not yet known. All the evidence points to the major effects occurring in the low energy particle radiation.

X-radiation at the top of the atmosphere

One of the most interesting new discoveries arising from the IGY program was the identification of radiation not of cosmic origin, but detected by cosmic ray instrumentation and techniques. In earlier years, it had been found, using rockets, that there existed a soft radiation in the auroral zone although this radiation was not directly observed in association with aurorae. During the first few months of the IGY, two series of cosmic ray balloon flights revealed that soft radiation is sometimes present at much lower altitudes in the atmosphere, and in addition, that the soft radiation occurs at the same time as aurorae are observed overhead from the ground. Outstanding events were observed on July 1, September 12, September 21, 1957, and February 11, 1958. This same kind of radiation was observed during one of the balloon flights undertaken at the time of the large cosmic ray intensity decrease of August 30, 1957, referred to in the previous section.

We have here a clear example of the way in which cosmic ray exploration extends our knowledge of nearby fields of research. It is expected that the existence of X-rays in association with the observed aurorae will place new conditions upon the selection of a unique theory for the origin of the aurora. The recently observed soft radiation trapped in the earth's magnetic field which has been detected by the Explorer I and III satellites appears to be connected with these observations. Experiments to be conducted during the coming year will undoubtedly clarify and lead to a solution of this problem.

Cosmic ray experiments on the earth's magnetic field

The magnetic field of the earth has been measured in detail over its surface for many decades, and by mathematical analysis its form in the space extending outward from the earth has been computed. This description of the magnetic field has been used for many years to explore the deflection of charged particles and other geophysical phenomena which involve the earth's magnetic field. However, recent cosmic ray studies under the United States IGY sponsorship have shown that there are significant discrepancies between the assumed description of the field and the description obtained by experiment with cosmic ray particles. Since cosmic rays are deflected by magnetic fields they act as probes to reveal the distribution of the magnetic field in the regions surrounding the earth. Investigations for the location of the magnetic equator for cosmic ray particles was begun with the U. S. S. *Atka* and by three round-the-world Antarctic expeditions of the U. S. S. *Arneb*, carrying cosmic ray neutron intensity monitors back and forth across the Equator. This was followed by a major aircraft expedition around the world to complete the measurements. The experiments show that the magnetic center of the earth for cosmic rays is displaced more than 40° from its present assumed position and that the Equator

itself is shifted such as to suggest that part of the new effect may be due to an interaction of the geomagnetic field with the ionized interplanetary medium. Additional equatorial cosmic ray measurements are being conducted through a joint Swedish-Canadian-United States effort. It is interesting to note that Pravda confirms these new United States results on the location of the earth's magnetic field by repeated cosmic ray observations on Sputnik II.

At higher latitudes the analysis of the geomagnetic field is being undertaken by studying the cosmic ray alpha particle intensity and energy distribution. Significant discrepancies with theory are also found at these latitudes.

The cosmic ray research conducted under the auspices of the IGY continues to reveal the fundamental importance of electromagnetic phenomena in interplanetary space and in the vicinity of the earth. High-temperature gas plasmas ejected by the sun and magnetic fields all take part in producing the effects observed at the earth. These studies have important consequences for our understanding of interplanetary space and the major magnetic storm effects at the earth. Cosmic rays provide a unique tool for these investigations. This has been an area of research where for the past several years the United States has shown scientific leadership.

II. GEOMAGNETISM

The main part of the geomagnetic field has its origin within the earth but there is, in addition, a fluctuating component of the magnetic field which can be observed with magnetic recording instruments. This latter variation is of great significance for scientists investigating the electromagnetic conditions in the earth's atmosphere and the space immediately above it, since it is believed that these magnetic field fluctuations arise from electric currents flowing in the upper atmosphere. It is this fluctuating component which contribtues significantly to the geomagnetic storms and correlates with solar activity, ionospheric effects, aurorae and cosmic ray phenomena.

Because of the interdisciplinary importance of geomagnetic studies 30 countries throughout the world are operating 129 magnetic observatories, from the North to the South Pole and in almost every region of the earth's surface; 31 of these stations are part of the United States program in geomagnetism. Newly established United States IGY geomagnetic stations are in operation in the Arctic, in the Pacific Ocean, in the continental United States, and in South America with the cooperation of IGY scientists in Peru. Some of these stations are arranged in chains over a wide range of latitudes and longitudes to study the details of the magnetic storm effects which occur during solar disturbances.

At the present time the amount of data available from the many stations undertaking studies of geomagnetic storms is not large because the data are not reduced and corrected for various effects. However, there are two results obtained from the first 11 months of study during the IGY which should be brought to your attention at this time.

Evidence of the equatorial electrojet

It has been suggested, but not previously established, that some of the magnetic effects observed on earth during magnetic storms are due to great electric currents of several hundred thousand amperes which follow paths circling the earth high in the atmosphere. Two such paths are believed to circle the North and South magnetic poles while the third circles the earth at the geomagnetic equator.

Stations in South America and in the Pacific Ocean—at Guam and Koror in the western Pacific, and at Jarvis, Palmyra, and Fanning Islands in the eastern Pacific—were established especially to study the existence of the so-called "electrojet." The electrojet is believed to be the equatorial electric current, but narrowed down into a "neck" of limited horizontal dimensions with consequent increased current density and intensified activity at local noon. The United States Coast and Geodetic Survey, which operates many of the magnetic observatories established by the United States, reports tentative confirmation of this phenomenon. Initial data from Koror reveal the existence of the equatorial electrojet and its rather limited horizontal extent.

Sub-audio-frequency fluctuations

Finally, an interesting special program for the recording of sub-audio-frequency geomagnetic fluctuations may be cited. These data are now being gathered at three field stations situated in Boston, Denver, and Thule, Greenland. Visual recordings of the signals reveal that a number of the waveforms, if increased in frequency, would be somewhat similar to those of radio audio-fre-

quency signals known as whistlers, tweeks, etc. The similarity of the geomagnetic wave forms having a frequency of one cycle per second to these phenomena has been shown by playing tape recordings of the magnetic signals at greatly increased speeds. Since it is currently believed that some of the radio noise associated with radio whistlers is due to ionized gas entering the magnetic field of the earth it is clear that these geomagnetic studies have a close connection to the studies of the transient conditions in the nearby interplanetary medium.

Dr. SIMPSON. Mr. Chairman and gentlemen, I am really delighted to be able to present for the record a prepared account of the major results in cosmic ray research and the program in geophysics and geomagnetism for the first months of the IGY. It so happens that many of the scientists in these programs actually began their research some months before the IGY on their own and were already in business at that time and some of the results occurring so early in the IGY are accounted for in this way.

What I would like to do today is to tie together a few of these new results and to try to give you a general picture of what the new ideas are that are evolving from the studies in these two fields.

They cannot be isolated, however, from the remarks which have been made by the previous speaker, Mr. Shapley, because, indeed, the effects which I will describe have their origin at the sun.

SOLAR-TERRESTRIAL RELATIONS

We ask the question, how is it that large geomagnetic storms occur at the earth. These storms, incidentally, have many dramatic effects, some of them being known to you for many years in the past, such as the failure of telegraphic communication links due to line surges, transient currents flowing through various types of communication circuits, blackouts in radio communications, and then nature's response; namely, the aurora phenomena that are even more subtle.

How is it that the sun suddenly lets loose with an enormous burst of energy, as observed by, let us say, visual observers, radio astronomers, or the person looking at the magnetic field in the sun so that he sees this effect and then a day later sudden dramatic effects occur at the earth? How does it come about when presumably the intervening space is almost a vacuum in our earlier ideas?

There is very little knowledge about the tenuous link.

Mr. THOMAS. How far away are you?

Dr. SIMPSON. About 93 million miles away.

Mr. THOMAS. A short distance. In point of time, how far away?

Dr. SIMPSON. If you are sitting on a light beam, you will travel there in about 8 minutes.

Mr. THOMAS. Go ahead.

Dr. SIMPSON. How is it that the enormous event on the sun can result in a dramatic effect on the earth? Let us look at this problem in its simplest details.

SOLAR OUTBURSTS AND PARTICLE STREAMS

Many years ago, and even currently, scientists have had the idea that the sun, in producing some of the effects of the earth, has essentially emitted a burst of ions, a stream of ions. You might imagine it to be something like an enormous fire hose of ions (ions being

charged low energy particles, such as you would encounter in the gas discharge of a fluorescent light bulb) but all collimated so they move out in a stream. Then this enormous hose goes switching out in the solar system. Occasionally the earth finds itself in a position where it is swept across by the stream. This looked like a very nice, reasonable, comfortable way to picture the whole situation so that every revolution of the sun resulted in an effect on the earth.

Indeed, this is known historically, as these effects on the earth recur with just the right time to account for the solar rotation itself. You would say there we have the effect. But, again, around 8 or 10 years ago, and, in fact, it was known from the beginning that there were many discrepancies, this did not seem to fit the picture. There is something fishy about the whole affair.

As you might imagine, you cannot see the stream. You cannot shine a little beam through it and then observe the fact that it absorbs light. It is too diluted. You cannot, in general, propagate a radio wave through it, because it will not do anything to the radio wave. How do you detect it? It has no color and only certain properties that arise because of electromagnetic effects. In the course of trying to investigate these matters over a number of years, it became clear that we would have to look to other areas of science for possible ways of probing the effects occurring in the interplanetary space that were fundamentally electromagnetic effects.

PROBES TO STUDY THE STREAMS

One of these techniques is the technique of using a basic proton of a fast-traveling charged particle, namely, a cosmic-ray particle. For example, if you were to take a hydrogen atom, which is composed of a proton nucleus and an electron, and strip the electron off and hit the proton with a bat, so that the bat knocked it up to around a billion electron volts of energy, this would be the energy equivalent to about 100 times the release of energy of a uranium-fission atom, something of that order, and you would have a low-energy cosmic-ray particle. This would be the low end of the spectrum. From this low-energy end to around a billion times greater or more you find the cosmic rays.

DEFLECTION OF COSMIC RAYS

These charged particles have an interesting property in that they are all charged particles and are deflected in a magnetic field. For example, you could imagine this room being made up of two side walls, one wall being the north pole of a bar magnet and the other side being a bar magnet stuck in the wall from the opposite side. Here is the south pole and here are the lines of force that you have drawn, as you remember in high-school days, running across the room. You take a cosmic-ray particle and project it across the room, and you discover that it is deflected. It curves in the magnetic field. It is the same phenomena that you have with a cyclotron spiraling and holding particles in an orbit while you give them additional energy. It has this very interesting property, namely, that a charged particle is deflected in a magnetic field and it is that which enables one to explore in a new way the electromagnetic properties of interplanetary space.

If you have a very low energy particle and a magnetic field in interplanetary space, the low energy particle will encounter the magnetic field but it is really attracted by this field and it may find itself just spiraling in the field and never get out of that field. If the magnetic field lies between the source of the particles and you, the particle will leave the source and enter the magnetic field and spiral in it and can be trapped. You will not see the particle arrive at the earth. In a way, this is a detector. If you knew that particle left at a certain position and you knew something deflected it, the only thing that could influence it would be a magnetic field. Here is a detector.

DETECTION OF COSMIC RAYS

Even more important are the higher energy particles which may be deflected in the field but still pass through. These particles have certain properties on arriving at the earth and in producing a big bang in the atmosphere by their collisions due to nuclear processes.

You say a particle arrived, but in a position different than that predicted by a simple theory of space between the source and myself. You say it was free of the magnetic field. We say, "Here we have a simple means whereby it is possible to use the particles coming from all over the galaxy to our solar system, entering our system, with a very small number of these particles arriving at the earth."

Then using these as probes, carriers of information, the information they carry is that they started in a certain direction. They had a certain configuration, but they were disturbed in arriving freely at the earth by the existence of certain kinds of magnetic fields.

MAGNETIC FIELDS IN SPACE

Using these techniques over a period of years, it is becoming increasingly apparent that there exist magnetic fields in interplanetary space, and these fields exist from time to time in many cases in accordance with the consequent burst at the sun. It comes about apparently somewhat as follows:

I might describe it very briefly on the board to you because I think that this has a bearing on all of the effects which occur outside of our own atmosphere, as we normally know it.

GAS CLOUDS FROM THE SUN

You can summarize the increasing evidence as follows: This is the sun. This is the axis of rotation of the sun, and somewhere, 93 million miles away, is the earth. If you will allow me I will bring it slightly closer.

Now, I am going to give the earth a magnetic field and put a small bar magnet in the earth and incline it, as Mr. Shapley said.

Mr. THOMAS. Twelve degrees?

Dr. SIMPSON. About 11 degrees from the axis.

Now, I will place a magnetic field that is not only confined to the interior of the earth, but extends out into the planetary medium, something like this, and now we have a system rotating a magnetic field, that lies extended out in space thousands of miles.

The sun suddenly releases a tremendous burst of gas, the details of which I will not go into here. We know that on occasion this burst, this release of energy, comes to 1,020 million megatons of H bombs. This amount released in the order of 10 minutes is the amount of energy released into the gas, into the whole system, in a very tiny region of the sun, maybe 10 times the size of the earth.

Mr. YATES. How can you measure this energy? How do you know it is the equivalent of 1,020 million megatons?

Dr. SIMPSON. This is a lower limit. It cannot be less than this amount because of the evidence. I will come to that in a minute.

Mr. YATES. All right.

Dr. SIMPSON. That will fit into the story in just a moment. Here we have a high temperature phenomena. In this region out here the temperatures are known to be in the order of 1,000,000°. Therefore, this gas cannot remain as an ordinary gas. It is stripped of all its electrons and is highly charged and is more conducting than a bar of copper. This burst of gas then proceeds outward and because it is conducting, there are currents flowing all through it in this diluted gas. When you have a current flowing in a wire, as you recall, you set up a magnetic field. You know how you build that up, you take a bar of iron and wrap a wire around it and then put a battery across the terminals and you generate a magnetic field. In the same way you generate a magnetic field in this system.

Mr. THOMAS. Do not forget to explain how you know you got a magnetic field.

Dr. SIMPSON. All right.

At some point in here, whether you consider the whole region as this advancing, enormous cloud, cosmic rays come from the galaxy and have to pass through this. Scientists have found that if you are an observer at the earth, the cosmic radiation intensity on the earth can be dropped to one-half its normal value by such an advancing cloud because the magnetic field reflects the cosmic ray particles, and some of them are deflected back away before they get to the earth and others have to walk their way through all of this tangled magnetic field and experiencing all of this deflection.

The net result is that by looking at the records of cosmic rays on the earth under suitable circumstances, one can tell that there is this postulated system of high temperature gas approaching the earth. That is the first part of the story. Here we have a means of probing an agent that has otherwise been inaccessible to us. It is diluted and at high temperature and you can imagine that this system may collide with the earth. We say "collide" with the earth and we really mean collide with the magnetic field of the earth, because this high-temperature gas is going to collide with the magnetic field and the magnetic field is going to have to find its way into the conducting gas. You also know from your elementary high-school physics that if you try to take a copper rod and pull it rapidly out of a magnetic field you experience a force reacting against the copper bar. It is an eddy current effect, trying to keep the copper bar in the magnetic field. Similarly, if you try to push the copper bar in very rapidly, you find that you are being held back, so you get a push-pull action of this high-temperature gas on the magnetic field of the earth.

In this way there are certain types of magnetic storms that are believed to occur.

MAGNETIC FIELD EFFECTS

Just squeeze the earth's magnetic field and you, as a little observer here at X, may say, "The magnetic field seems to have taken a change and here is a way of explaining the overall effect."

This is one of the results now in IGY which is becoming more firm. It started before, but it is now becoming firm.

Another consequence in geomagnetism is that one measures these effects. It takes about a day for this burst to transport all of the gas across the system and this accounts for that delay that was referred to by Mr. Shapley. This is another possible explanation that we see for the delay. You see it one day, wait a day, and then suddenly the aurora occurs, magnetic storms occur on the earth, and you have a rough idea of the complex electromagnetic phenomena that occur.

FLARES AND COSMIC RAYS

One more point. On the earth we observed not only the gas of the solar flare, but the fact that on this rare occasion nature even manufactured cosmic rays locally. Cosmic rays generally are manufactured throughout our galaxy and on occasion you get the manufacture here (pointing to figure). This is like a miniature cyclotron at this point (pointing to figure).

On such an occasion the particles are projected outward and arrive at the earth and because you have your knowledge of the energies of these particles and their distribution and their storage in space around you, you set a lower limit for the amount of energy contained in all of the cosmic rays produced by the sun and from this you can determine what the lower limit was for the initial gas burst itself. You come up with the number I mentioned earlier.

In the course of doing this, you also discover that nature has provided us with a box that keeps the cosmic rays around for a while if they are produced in here. That box is a magnetic field of some sort that has dimensions much larger than the center distance.

As though you had suddenly released a flashbulb in the dark, suddenly you see the sky and new and different forms of magnetic fields, very diluted but present, and this is one of the other conclusions that one can derive from cosmic rays. What we are saying is that we are interested in a new area of exploration where we are dealing with magnetic phenomena, transient type effects, that are of considerable importance and, in fact, they are of quite fundamental importance. We are exploring them right at the surface and in the future will be exploring them very extensively by putting up satellites and rocket probes to go out into this region to try to decide among the various rays how these new ideas fit together. So, in these coming years some of the most important uses for satellites and rockets will be the exploration of the electrodynamics of the solar system, the electrodynamics of the region around the earth, and this region is

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right on our doorstep; and the most fascinating discoveries lie right on our doorstep which I like to define as a 500,000 mile region extending, roughly, out around the earth. This [indicating] is the nearby region you play in; and within this region, we have sitting plums of new ideas that are open to any scientist who cares to take these steps and will have the right apparatus at the right place at the right time.

MAGNETIC FIELD CONTROL OF PARTICLES

You might imagine that this magnetic field has some role in sorting out the particles as they come in and that is indeed the case. The charged particle moving in is deflected and in fact we use the earth's magnetic field as an analyzer, instead of a small magnet in the laboratory as you would for low-energy particles. You put a beam through the magnetic field and it is deflected and from the deflection you tell what the energy is. Here the energy is so high you have to use the whole magnetic field of the earth to produce an appreciable effect on the high-energy particle so you can measure its energy.

In the course of using the magnet we have learned some new things about the magnetic field itself because we have fed back the information that the particle coming in has given on the shape that the magnetic field has, and we have known the shape of the earth's field for over 100 years.

SHAPE OF THE EARTH'S MAGNETIC FIELD

It must, therefore, have a certain form in space. It must look like the shell of an apple, a nice and uniform particle with lines of force extending the way I have indicated here, and we can describe it mathematically, but the results of experiments do not fit the mathematical description. A whole series of experiments have been done including the use of Sputnik II which confirms the results of the United States in this matter. This little bar technique, so far as particles coming from great distances is concerned, is not where we have been placing it in early years. The geomagnetic field in interplanetary space is as though this little bar is shifted westward about 40° and the magnetic center of the earth is rotating around at about 45° or 47° from the position which is classically accepted on the basis previously used in making magnetic measurements. You learn what the field should be, but it does not fit. So we are now in the situation of trying to explain why it is that this magnetic field in interplanetary space is so different in its description from the field which is predicated on the basis of this being a vacuum.

Mr. YATES. Is that because you were wrong in the first instance in placing your bar or because it has shifted?

INTERPLANETARY GAS

Dr. SIMPSON. No; in fact, at the surface of the earth you get the right answer, but it is as you proceed outward where the discrepancy increases, and we think it is because the region of the space in which the earth moves is not in a vacuum, but in a very diluted residual gas at relatively high temperatures. This has an important effect on the thing. Very close to the earth, of course, we have the newly veri-

fied electrojet current system involving hundreds of thousands of amperes of current flow around the earth. In the polar regions and others these occur at different times.

DISCOVERY OF X-RAYS AND ELECTRONS

One additional new facet of this was a series of cosmic ray measurements which led to the finding of X-rays under the aurora—you see it and you find cosmic ray particles, but cosmic ray particles plus some X-rays there. This was discovered in the first days of the IGY. These experiments and the experiments on high energy cosmic rays which I just described, and the geomagnetic field studies, and finally the newly found soft radiation which is observed by Explorer I and III, which I believe Dr. Porter will discuss, essentially may be interlinked in this whole effect. These phenomena are all interrelated. One possible explanation for this low-energy radiation observed by Explorer I—and incidentally it is not cosmic rays; we are not talking about cosmic rays in this—it seems to me is that they are low-energy electrons simply drifting and spiraling in the magnetic field. They are deflected in the magnetic field and they spiral from one position and then may be reflected back again and thus are stored in this region until they escape.

If you were to go through this region you would actually find a region of space that is occupied by these low-energy electrons that have properties similar to your doctor's X-ray machine; namely, electrons starting out which are accelerated to the target and produce X-rays, and in this case you get the radiation observed in Explorers I and III. The origin of these low-energy radiations and the origin of the low-energy electrons may be related, and probably are intimately related to these types of gas clouds that extend out from the sun.

OUTER ATMOSPHERE OF THE SUN

Finally, I think it is becoming increasingly clear that the earth is moving in what one might call the outer atmosphere of the sun itself. The sun can be thought of as having an atmosphere extending out well past the orbit of the earth. We know that out at great distances from the sun—the bright ball as you observe it—the temperature rises to the order of 1 million degrees and then drops off in some manner. We do not know at the earth what the gas temperature is, but it is probably somewhere between 20,000° and 100,000°. Some calculations have indicated even higher temperatures.

Mr. THOMAS. At what distance are they from the earth?

Dr. SIMPSON. Well, say, 2 or 3 earth radii or about out in here [indicating]. So, we get an entirely different view of a region that we have not had access to in the past, and this is only the beginning.

The implications of all these studies are interesting for other areas of research. We know in these days that we have large groups working on thermonuclear reactions. There is a great possibility that the thermonuclear processes that are being studied at present are actually of the kind which occur with the energy release right at the sun, and that some of these high-temperature gas effects that trap particles are related to the experiments which are being conducted in laboratories and in an entirely different area. But what we learn here

bears upon what we called then hydromagnetism, which was referred to in the introduction by Dr. Kaplan, because it is the hydromagnetic theory that explains this phenomenon. And as I mentioned, it may have a bearing on our future understanding of new methods of propulsion, but they also have a very fundamental relationship to our understanding of generating thermonuclear power.

Out of all these studies one in the future may hope for an interlinking not only of the geophysics and astrophysics but also the problems of power production from the light elements.

Mr. THOMAS. Wonderful. Thank you a million.

RELEASE OF ENERGY

Mr. YATES. You have stated there are 1,020 million megatons of energy that start out from the sun. We are protected in some way on earth from the full force of that. But we are being unprotected by our own bursts that we explode on this earth. I gather from what you said the process seems to be similar according to some theory between the things that take place on the sun and what man has been able to create. Is my premise correct so far?

Dr. SIMPSON. The effects we discussed were equivalent energy effects. I do not want to convey the idea that the way in which the H-bomb releases energy is the way in which this solar event releases energy. This is not true. I am trying to give you a feel for the amounts of energy which are stored in the system, and I do not have at hand any yardstick other than just our findings on H-bombs which we have accumulated from 1954 as a calibration. We take multiples of those and that gives us a new sort of general scale of the energy to work with.

Mr. YATES. I find disturbing the fact that we are protected from the sun's outbursts but we are generating a like force, not as great, of course, on our own upon the earth.

Are we going to move toward capturing and releasing higher and higher amounts of energy so that ultimately we place ourselves in a position where we do destroy ourselves?

Dr. SIMPSON. No, sir. I think here we are dealing with the release of energy at a considerable distance so that if you would ask a question: 93 million miles away how much of the energy falls upon the earth in one form or another? It is exceedingly small.

Mr. YATES. But we are on the earth and we are not protected by the layer of atmosphere.

Where will we stop in the creation of this form of energy ourselves?

Dr. SIMPSON. I do not know. You mean on earth?

Mr. YATES. We now have a megaton bomb?

Dr. SIMPSON. Yes, sir.

Mr. YATES. We are moving toward, say, a 2-megaton bomb, I assume, because you are capturing the means of making more and more energy through these experiments.

Dr. SIMPSON. Yes, sir.

Mr. YATES. If I remember my history, when the scientists first exploded the atomic bomb, they were afraid of what was likely to result from the chain reaction. They thought this would be an uncontrolled force that might destroy the earth.

Dr. SIMPSON. Yes, sir.

Mr. YATES. Is there still a possibility of that?

Dr. SIMPSON. I think a study group looked into this very seriously about 2 or 3 years ago and there was rather conclusive evidence that you really cannot trigger off a fusion or a fission bomb so that it will perform this function.

Perhaps Dr. Kaplan recalls this study. It was about 3 years ago that an AEC committee looked into this matter.

Dr. KAPLAN. I do not think I was involved in that.

Dr. WATERMAN. They looked at it quite a bit earlier because that was one of the big worries in the early stages when they feared that an atomic bomb might create that possibility. They did look at it at that time and they continue to do so. Their conclusion has been that it is a very difficult thing to make an atomic bomb which would do that and that it would be almost impossible to detonate anything more than the ingredients you put in. That has been the conclusion so far. It is a very hard thing to make an atomic bomb of that nature and it will have no effect on nature. This effect, incidentally, or the possibility of it, was predicted back in 1924 and at that time the man said if we ever learned to make a hydrogen and helium combined apparatus the success of the experiment might be published to the world at large in the form of a new birth of a new star.

Mr. THOMAS. Off the record.

(Discussion off the record.)

Mr. THOMAS. Dr. Porter, we shall be glad to hear from you at this time. You may proceed and make your presentation in any way you desire. Then, we will all be back tomorrow to complete this hearing.

IGY SATELLITE PROGRAM

Dr. KAPLAN. May I say before Dr. Porter speaks that there have been earlier times at these meetings when the University of California was thanked for the way it has released me, and I think all of you know that in recent months we have not allowed General Electric to use Dr. Porter. He is a hard-working man.

Mr. THOMAS. We are delighted to have you, Dr. Porter.

Dr. PORTER. Mr. Chairman, I am delighted to be here because this has been one of the most interesting assignments I have ever worked on in my life. I enjoy being here talking about it, as you know.

I have put together some information on the program and a description of some length of the work that has been done in the program and request that it be a part of the record of this testimony.

Mr. THOMAS. Without objection, your statement will be inserted into the record at this point.

(The statement referred to follows:)

IGY EARTH SATELLITE PROGRAM

Satellites share with rockets the ability to carry scientific instruments to extremely high altitudes where extraterrestrial particles and radiations can be examined before they are absorbed, reflected, or modified by the atmosphere. Satellites, however, permit these measurements to be made over wide areas for much more extended periods. Furthermore, the speed of satellites allow nearly simultaneous measurements from large areas and ranges of altitudes—a fact which is important to synoptic studies. In addition to scientific measurements by means of internal instrumentation, satellites make possible a unique class of experiments which depend upon orbital measurements.

The IGY program in general, and the earth satellite program in particular, depend for success upon large-scale cooperation both nationally and interna-

tionally between scientific institutions, government, and private industry. It is gratifying to report that such cooperation has been received. This is especially true of the Department of Defense. In addition to the Department's mission to provide launching vehicles and to the contributions by DOD research laboratories, all three services have provided extensive logistic and operational support.

One of the goals of IGY is to obtain coordinated worldwide geophysical data. Since the satellite does just this, it is particularly appropriate that satellite research has been inaugurated during IGY. Furthermore, since satellites pass over many countries, the cooperation of these countries is essential for obtaining adequate tracking and telemetry data. Extensive cooperation is being received from many IGY participating committees. These committees are cooperating in one or more of the following ways: (*a*) support (and, in several cases, complete operation) of 1 of the 12 precision optical tracking stations and/or 1 of the 11 precision radio tracking stations; (*b*) construction and operation of one or more volunteer radio tracking stations; (*c*) reception and recording of telemetry data for those experiments for which meaningful data can be obtained; (*d*) organization of one or more volunteer satellite observation stations.

SATELLITE VEHICLES

The two satellite launching vehicles in the program are the Vanguard and the Jupiter–C. As you know, the former has been developed by the Naval Research Laboratory, the latter by the Army and the Jet Propulsion Laboratory.

The Vanguard launching vehicle is representative of the type of rocket required to place in orbit a payload of approximately 20 pounds. This vehicle is a 3-stage unit, with the first 2 stages guided, and the third, spin-stabilized. The Vanguard is 72 feet long and 45 inches in diameter. Total weight at launching is about 22,000 pounds. The first stage delivers a thrust of 27,000 pounds to start the system on its flight. When its fuel is exhausted, about 142 seconds after takeoff and at some 33 miles altitude, the system has attained a velocity of about 6,075 feet per second. The second-stage rocket with 7,500-pound thrust then takes over, attaining a velocity of about 14,700 feet per second, burning out at about 122 miles (195 kilometers), and coasting onward. When an altitude of about 261 miles is reached, the third-stage rocket accelerates the satellite in a horizontal direction to a velocity of about 26,000 feet per second. The entire sequence is completed about 10 minutes after takeoff time.

The overall length of the modified Jupiter–C vehicle is 823.3 inches. The first stage is a modified Redstone liquid-propellant rocket 672.8 inches long and 70 inches in diameter. The upper-stage assembly, which is separable from the carrier vehicle, is 150.5 inches in length. After the main powerplant is expended, it separates from the nose section containing the upper stages together with suitable altitude controls for use during the coasting period. As this nose section reaches the apex of its ballistic trajectory, the second-stage rockets fire, followed in rapid succession by the third-stage rockets, and the fourth-stage rocket, the empty shell of which remains attached to and forms a part of the satellite body. The expended powerplant, the separated nose section, and the second- and third-stage rockets, of course, drop into the ocean at successively greater distances from the launching site.

The first stage of the Jupiter–C vehicle thus provides all of the energy to lift the payload to the prescribed distance from the earth. All other stages of the rocket increase the speed but do not immediately carry the satellite to a greater height. The upper stages are spin-stabilized at 700 revolutions per minute in order to reduce the effect of thrust misalinement. Small electric motors, mounted within the nose section of the main stage, provide the necessary spin torque. The second and third stages consist of clusters of solid propellent rockets; the final stage is a single solid propellent rocket.

ORBITAL INFORMATION AND DESCRIPTION OF SATELLITES

All of the United States satellites have been launched from Patrick Air Force Base at Cape Canaveral on the east coast of Florida. Since the last stage of each vehicle is designed to reach a velocity more than sufficient to maintain a circular orbit, and also since some small error in launching angle is to be expected, these satellites assumed elliptical orbits, with perigee of 110 to 400 miles and apogee of from 1,500 to 2,500 miles. In each case the inclination of the orbital plane to the equatorial plane has been about 34°. Between 115 and 134 minutes were required for each of the United States satellites to complete its initial circuit around the earth. Therefore, since the plane of the orbit does not follow the rotation of the earth, successive transits are displaced about 30° with respect to geographic longitudes. These two factors, inclination of the orbit to the equator and the geographic displacement of successive transits, allow extensive coverage in the latitude belt between 40° N. and 40° S.

As is well known, the U. S. S. R. has launched three satellites as a part of its IGY program. The general characteristics of the first two of these satellites were provided by the Soviet committee to the IGY in a preliminary report on launching in the U. S. S. R. of the first and second artificial earth satellites. The launching of the U. S. S. R. satellites provided an opportunity for additional scientific investigation from ground-based measurements. Accordingly, a number of changes have been made in the United States program, outlined elsewhere in this discussion.

A tabular summary of the first five satellites is as follows:

IGY satellite table, May 28, 1958 [1]

	1957 Alpha (Sputnik I)	1957 Beta (Sputnik II)	1958 Alpha (Explorer I)	1958 Beta (Vanguard I)	1958 Gamma [2] (Explorer III)	1958 Delta (Sputnik III)
Weight (pounds)	184	1,120	30.8	3.25	31.0	2,925.
Shape	Sphere	Complex	Cylinder	Sphere	Cylinder	Conical.
Dimensions	22.8 inches in diameter.		80 inches long; 6 inches in diameter.	6.4 inches in diameter.	80 inches long; 6 inches in diameter.	11 feet 9 inches long; 5 feet 8 inches wide at base.
Shell composition	Aluminum alloys.	Aluminum alloys	Steel with 8¼-inch aluminum oxide stripes.	Aluminum	Steel with 8¼-inch aluminum oxide stripes.	Aluminum alloys.
Antennas	4 spring-loaded whip antennas, 7 feet 10.5 inches to 9 feet 6 inches.		1 turnstile antenna with 4 whip elements each 22.5 inches long; a dipole antenna using the skin of the satellite itself.	1 turnstile antenna and 1 dipole antenna with total of 6 12-inch rod elements.	2 dipole antennas using the skin of the satellite itself.	Folded dipole antennas; trailing rod antennas.
Experiments	Internal temperatures and pressures and other data.	Cosmic rays; solar ultra-violet and x-radiation; test animal (dog); temperatures, pressures.	10.63 pounds: (1) cosmic rays; (2) micrometeorites, (*a*) impact and (*b*) erosion; (3) temperatures, (*a*) internal, (*b*) rear skin, (*c*) front skin, and (*d*) nose cone.	1.06 pounds: temperatures.	10.83 pounds: (1) cosmic rays with tape recorder feature; (2) micrometeorite erosion; (3) temperatures, (*a*) skin and (*b*) internal.	2,134 pounds: atmospheric pressure and composition; concentration of positive ions; magnitude of satellite's electrical charge and tension of earth electrostatic field; tension of magnetic field of earth; intensity of sun's corpuscular radiation; composition and variations of primary cosmic radiation; distribution of photons and heavy nuclei in cosmic rays; micrometeors; temperature measurements.
Transmitters	(*a*) 20.005 megacycles; (*b*) 40.002 megacycles.	(*a*) 20.005 megacycles (*b*) 40.002 megacycles.	(*a*) 108.00 megacycles at 10 milliwatts (1, 2 (*b*), 3 (*c*), and 3 (*d*), above) (*b*) 108.03 megacycles at 60 milliwatts (1, 2 (*a*), 3 (*a*) ,and 3 (*b*) above).	(*a*) 108.00 megacycles at 10 milliwatts; (*b*) 108.03 megacycles at 5 milliwatts.	(a) 108.00 megacycles at 10 milliwatts (1, 2, 3 (*a*), and 3 (*b*) above) (*b*) 108.03 megacycles at 60 milliwatts (1 only).	(*a*) 20.005 megacycles.
Transmitter lifetime.	Both (*a*) and (*b*) ceased operating Oct. 27, 1957.	Both (*a*) and (*b*) ceased operating Nov. 10, 1957.	(*a*) Ceased operating May 23, 1958 (*b*) ceased Feb. 11, 1958; began again Feb. 24; ceased finally Feb. 28.	(*a*) Ceased operating Apr. 5, 1958 (*b*) will operate indefinitely.	(*a*) Telemetering and beacon signal stopped May 10, 1958; beacon resumed May 15; (*b*) ceased operating May 14, 1958; began again erratically May 22.	(*a*)
Power supply	Chemical batteries.	Chemical batteries	Mercury batteries	(*a*) Mercury batteries; (*b*) 6 groups of solar converters.	Mercury batteries	(*a*) Chemical batteries; solar batteries.
Perigee (miles)	138	132	224	404	118	143.
Apogee (miles)	598	1,009	1,573	2,465	1,740	1,181.

Period (minutes)	96.25	103.3	114.8	134.29	115.9	106.
Inclination to equator.	64.3°	65.4°	33.5°	34.25°	33.37°	65°.
Speed (perigee) miles per hour.	18,000	18,000	18,400	18,400	18,860	18,337.
Speed (apogee) miles per hour.	16,200	15,100	13,700	12,400	13,450	14,637.
Lifetime	Oct. 4, 1957-Jan. 4, 1958.	Nov. 3, 1957-Apr. 13, 1958.	Jan. 31, 1958 (3 to 5 years).	Mar. 17, 1958 (200 years).	Mar. 26, 1958	May 15, 1958.

[1] Initial orbital elements from Naval Research Laboratory, based on latest refinements.

[2] Explorer II failed to go into orbit.

On the day of the launching of the third U. S. S. R. satellite, the United States National Committee received the following radiogram from the U. S. S. R.:

"For information of national contacts, third sputnik is placed in orbit. Orbit inclination 65°, maximum height, 1,880 kilometers, period 106 minutes. Sputnik is separated from rocket casing. Sputnik weighs 1,327 kilograms. It has a conical form with base diameter 173 centimeters and height 357 centimeters. It contains radio transmitter for telemetry and orbit determinations. One transmitter radiates continuously with great power level on 20,005 kilocycles. Sputnik has ordinary and solar batteries. Experiments carried include atmospheric density and composition, density of positive ions, electric charge of sputnik, electric field of earth, geomagnetic measurement, corpuscular radiation of sun, composition and intensity of cosmic rays, micrometeoric impacts, temperature measurements. Sputnik and its rocket may be visible during sunrise and sunset under favorable conditions." Additional information was published in the Soviet press and translations are available.

All of the satellites in the Vanguard series, save the test sphere and one of the fully instrumented satellites, will be made of magnesium, will be spherical in shape, about 20 inches in diameter; and will weigh approximately 21.5 pounds. The one exception will house a magnetometer and will necessarily be made of a nonmagnetic material such as fiberglass. This satellite will be about 13 inches in diameter and will house the sensing coil in the end of a narrow foot-long cylindrical protrusion. Accompanying the magnetometer will be a 20- or 30-inch inflatable satellite for air-drag measurements.

Design, testing, and final packaging of the Vanguard series of satellites is being done at the Naval Research Laboratory. Similar work for the Explorer satellites was done at the Jet Propulsion Laboratory of the California Institute of Technology.

TRACKING PROGRAMS

Radio tracking

Whereas present plans for optical tracking are limited to satellite transits which coincide with clear twilight periods, radio tracking stations obtain data by day or night, in clear or poor weather, as long as the satellite transmitter and batteries work properly. This fact makes radio tracking especially desirable for acquisition, i. e., initially determining the orbital elements of a new satellite. In addition, the precision of radio observations is sufficiently high to be of general scientific value. Radio observations, although less precise than certain optical observations, are generally more closely spaced; this fact is expected to be especially valuable in the task of disentangling perturbations due to gravitational anomalies.

The field of view, or antenna beam width, of each Minitrack array of receiving antennas is 100° in a north-south direction and 10° in an east-west direction. This fan-shaped intercept pattern was especially designed for the Minitrack stations which string from north to south, approximately along a 75th meridian "picket fence," at the following locations: Blossom Point, Md.; Savannah, Ga.; Habana, Cuba; Mount Cotopaxi, near Quito, Ecuador; Lima, Peru; Antofagasta, Chile; Santiago, Chile.

Coolidge Field, Antigua Island, was chosen as the site of an eighth station, so that observational data would be available soon after launching. Two other stations, located at Bloomfontein, Union of South Africa, and at San Diego, Calif., also obtain data on the first circuit of the United States satellites. An 11th station, located at Woomera, Australia, extends observations longitudinally. All stations have been operating successfully and United States satellites have been observed by at least one of the radio tracking stations on nearly every orbit. The Naval Research Laboratory which has the responsibility for radio tracking, reports that computations of 1958 Beta indicates that the Minitrack radio tracking system is now achieving accuracy close to its designed limit.

Optical tracking

Ultimate precision in tracking is provided by an optical system consisting of a primary net of 12 stations assigned to the Astrophysical Observatory of the Smithsonian Institution.

Observation stations use the Baker-Nunn satellite tracking camera and a Norrman crystal clock, model III. The tracking camera is a modified f/1 Schmidt telescope with a 20-inch apochromatic triple-element correcting system, and a 31-inch spherical mirror. This system is designed to give 35 micron or better images over a 5° by 30° field. The actual equipment delivered exceeds these specifications. The instrument is expected to be capable of photographing

rapidly moving satellites as faint as 13th magnitude. All IGY satellites to date have been photographed at one or another of the network stations with the possible exception of the 6.4-inch sphere. There is a photograph of one of the components of Vanguard I, but it is uncertain whether or not this observation is of the small test sphere or the third-stage bottle. Although the Baker-Nunn cameras are just beginning to swing into full operation, as of May 25, 1958 Alpha has been photographed by the Baker-Nunns 32 times; 1958 Gamma, 22 times; and 1958 Delta I and II, 58 times. The network obtained about 150 photographs of satellites 1957 Alpha and Beta, although many of these were taken with the interim equipment mentioned below.

Limitations of the optical tracking system are: (1) the path of the satellite must be previously known to an accuracy of 3 degrees; and (2) conditions of visibility will restrict optical observations of satellite transits which coincide with clear twilight periods.

Observation stations have been established at the following locations: White Sands, N. Mex.; Florida, near Palm Beach; Curacao, Netherlands West Indies; Arequipa, Peru; Villa Dolores, Argentina; Olifantsfontein, South Africa; Cadiz, Spain; Shiraz, Iran; Naini Tal, India; Woomera, Australia; Mitaka, Japan; and Haleakalas, Maui, T. H. Most of the stations are located in latitudes near 30° or 35° in order to maximize the number of possible observations of United States satellites. Two of the stations were chosen at middle latitudes near the "picket fence" to allow observations to be made when the satellite is visible at other than the extreme latitudes and also to provide a tie-in with the radio system. Baker-Nunn cameras and ancillary equipment have now been delivered to 11 of the 12 precision optical tracking stations and the majority of these are now in operation. The 12th Baker-Nunn left the United States last week for Hawaii. Smithsonian estimates that the entire network will be in operation at the end of June using Baker-Nunn cameras.

Launching of the U. S. S. R. satellites and delays in procurement of the Baker-Nunn cameras made it necessary to provide an interim plan for some of the stations on the latter part of the delivery schedule. The Congress provided funds for such an interim plan within the last supplementary appropriation. Accordingly, for the past several months some of the phototelescopic stations were equipped with various types of optical equipment other than the Baker-Nunn cameras. Two special tracking telecameras were made available by the Army; 2 Schmidt meteor tracking cameras were loaned from an Air Force program; and 3 cinetheodolites were provided by the Air Force. In addition, the Army supplied a number of temporary operators. Because of the recent greatly improved procurement schedule of Baker-Nunn cameras, it became unfeasible and relatively unnecessary to make use of the cinetheodolites. All interim equipment is now being returned.

SATELLITE LIFETIME AND AIR DRAG MEASUREMENTS

The atmosphere at satellite altitudes is extremely thin. Nonetheless, it constitutes the only significant dissipative force which the satellite encounters. If it were not for this very slight drag, satellites would continue to orbit indefinitely. The lifetime, as well as changes in period and apogee distance, are highly significant for more accurate inferences of air density at satellite altitudes. Satellites launched to date are not as suitable for air drag determinations as the spherical satellites yet to be launched. However, it has already been possible to improve our estimates of air density at satellite altitudes and a summary of such results is given later.

Air drag data for IGY satellites is determined from tracking observations. Observations made over an extended period of time yield accurate air drag and air density data for altitudes corresponding to the perigees of various satellites. A sufficiently long period of observation may enable detection of seasonal diurnal and latitudinal changes.

Observation of each satellite during its last days is expected to yield data on the air density below perigee altitudes. For altitudes above perigee, the National Advisory Committee for Aeronautics has developed a light inflatable satellite which will be measurably affected even by the thinner air of higher altitudes.

OTHER GROUND-BASED MEASUREMENTS

Geodetic determinations

Geodetic determinations require high precision and complex analytical techniques. Satellites launched thus far are not well suited for such precision and

analysis. For this reason and also because of the amount of time required for detailed post analysis, most of the significant geodetic data will be obtained from satellites yet to be launched. Eventually, it is expected that important new information will be obtained on the relative position of the continents, shape of the earth, size of the earth, and gravity anomalies.

Ionospheric measurements

The 20 and 40 megacycles transmitters used in the U. S. S. R. satellites, although not as precise as higher frequencies for tracking purposes, provide an excellent opportunity to study the propagation characteristics of the transmitted signals. As 1957 Alpha II and 1957 Beta transmitted on these frequencies, the USNC–IGY Technical Panel on the earth satellite program established a third working group and a number of new projects for the study of satellite ionospheric measurements.

A number of research organizations undertook recording of signals from 1957 Alpha II and 1957 Beta and now plan to analyze these data. These and other organizations plan to record and analyze data from existing and future satellites having appropriate frequencies. The American Radio Relay League, working with some of these organizations, developed a program whereby radio amateurs can make a substantial contribution to the studies of the ionosphere by means of satellite signals.

In addition to these types of investigations, measurements of the solar radiation in the Lyman-alpha and X-ray regions is of importance to ionospheric studies and satellite instrumentation has been prepared for making such measurements.

VOLUNTEER PROGRAMS

There are five distinct ways in which volunteers can contribute to the IGY earth satellite program. First, they may join together in visual observation teams using relatively simple optical instruments. Second, they may establish radio tracking stations in conjunction with amateur radio clubs, universities or other scientific groups. Third, telemetry signals from instrumented satellites may be recorded and forwarded to IGY centers for analysis. Fourth, they may participate in the ionospheric program mentioned in the previous paragraph. Fifth, volunteers may photograph satellite passages against the background starfield by means of high quality fixed cameras and special techniques.

Moonwatch

The volunteer teams for visual observation are organized into a special program designated "moonwatch," established over a year and a half ago under the auspices of the Smithsonian Astrophysical Observatory. Visual data are important for acquiring the satellites and for obtaining air density data in the final phase of each satellite's life.

To date, over 140 volunteer visual observation stations have been established within the United States. More than 100 additional stations have been established throughout the world in locations other than in the United States or the U. S. S. R. Some 50–70 stations have been established within the U. S. S. R. as part of the Russian equivalent of moonwatch.

Moonbeam

Volunteer participation in radio tracking, telemetry and ionospheric investigations is being handled through a program designated "moonbeam." The American Radio Relay League (ARRL) is actively supporting the program and is publishing pertinent technical information in its journal, QST. The moonbeam program was organized comparatively recently and involves somewhat sophisticated equipment, in particular, for groups who are tracking satellites. Hence the response has so far been less than that of moonwatch. The newest activity in the moonbeam program involves volunteer participation in ionospheric investigations. This new activity is based upon 20 and 40 megacycles satellite signals and utilizes equipment readily available to most radio amateurs. If large amounts of relatively simple data can be gathered, a statistic ionospheric study can be undertaken which might not otherwise be possible.

Phototrack

This program is being actively supported by the Society of Photographic Scientists and Engineers and is designed to obtain photographs of satellites against a background starfield. The position of a satellite's path can be determined with the high precision inherent in the photographic record. The phototrack program has wide appeal due to the value of the data which can be

obtained with relatively easy modifications of precision equipment presently available to professional photographers. More than 50 negatives meeting the phototrack specifications have already been obtained even though the program was not begun until after launching of bright satellites by the U. S. S. R.

Prediction data

Predictions are furnished directly to some of the observers and general worldwide distribution is effected through the IGY regional warning centers. Within the United States, the Civil Air Patrol, through its communications network and local chapters, is transmitting satellite prediction data on the evenings of working days to volunteers participating in the moonwatch, moonbeam, and phototrack programs. It is hoped that this channel will provide increasing service to the general public through direct listeners and through interested newspapers using the CAP as a source.

INTERNAL INSTRUMENTATION

The availaiblity of the Jupiter-C launching vehicle in addition to the Vanguard, has made possible an expansion of the internal instrumentation program. Preparation of all instrumentation packages is on or ahead of schedule. All instrumentation thus far flown has performed according to designed operation and a report on the preliminary analysis of data is given in a later paragraph.

Telemetry

Scientific data from satellite-borne instruments are transmitted to ground recording stations by modulated radio signals. Each of the primary Minitrack stations records telemetry as well as tracking information. These stations record any continuously transmitted data and also interrogate certain satellites using a command receiver and storage readout system. Tracking data itself is necessary to translate scientific data recorded in terms of time into data in terms of geographic position. Telemetry operation to date, both in the satellite and on the ground, has been successful. The batting average on successful interrogations of 1958 gamma has been about 75–80 percent.

Additional coverage is highly desirable for those satellites which transmit current data continuously. Two additional telemetry stations, strategically located near the geomagnetic equator at Ibadan, Nigeria, and Singapore, were established through the cooperation of the British National Committee for the IGY and local groups who are operating the equipment.

Environmental measurements

Because environmental measurements are important to the engineering design of satellites as well as to a better understanding of the upper atmosphere and exosphere, these measurements were designed for inclusion in the first United States IGY satellites. Temperatures of various places on the surface and in the interior of the satellites are made by means of thermisters and also by means of uncompensated crystals which cause slight changes in the frequency of the satellite radio signal. Meteoritic measurements will be made by means of specially prepared erosion gages, microphones, pressurized zones, and possibly opaquely covered cadmium sulfide photo detectors. The instrumentation for these measurements and the interpretation of data are the responsibility of the Naval Research Laboratory, the Jet Propulsion Laboratory, and the Air Force Cambridge Research Center. A radioactive type erosion gage has been prepared by the University of Maryland as an alternate method of meteoritic measurements.

Cosmic rays

The use of a single Geiger counter in an artificial satellite makes possible for the first time a comprehensive geographic, altitude, and time-variation survey of primary cosmic rays. This experiment, directed by the State University of Iowa, was prepared in two forms for use with the Jupiter–C rocket. The first form employed continuous telemetry only and was flown in 1958 alpha; the second incorporated a miniaturized tape recorder for data storage and was flown in 1958 gamma. Further details and results of these 2 satellites are discussed in section below.

Two additional cosmic ray experiments have been brought to the developmental stage and are held in a reserve status. One has been developed jointly by RIAS and Bartol Research Foundations for investigating cosmic particles of atomic number greater than eight. The other, developed by California Institute of Technology, is complementary to the Iowa study in that it would measure the total ionization of primary particles rather than the counting rate. This latter experiment also proposes to study extragalactic light.

Solar radiation

X-rays and far ultraviolet radiations do not reach the ground and therefore cannot be measured directly except by means of rockets or satellites. Measurement of X-ray and far ultraviolet radiation should contribute greatly to our understanding of astrophysics and of the ionosphere which is formed through the absorption of these radiations.

The Naval Research Laboratory has prepared a satellite experiment for measuring the intensity of far ultraviolet radiation in the Lyman alpha region of the hydrogen spectrum. The experiment is designed to measure and transmit continuously the current intensity of the Lyman alpha radiation and the peak intensity during the period of the preceding orbit.

A relatively simple modification will allow measurement of radiation in the X-ray region with an ionization chamber and filtering window similar to that used for Lyman alpha measurements.

Meteorology

Two experiments of fundamental significance to meteorology have been prepared for launching in earth satellites during IGY:

(i) *Cloud cover of the earth.*—Worldwide knowledge of the extent, form, identification, and movements of various types of clouds would contribute to accurate, short-term weather forecasting as well as to basic understanding of thunderstorms, hurricanes, radiation balance, and meteorology in general.

Some knowledge of this type can be obtained through a satellite instrumentation package prepared by the Signal Engineering Laboratories. The sensing elements of this satellite will be 2 infrared photoelectric telescopes which are pointed in opposite directions at an angle of 45° to the spin axis of the satellite. The spinning of the satellite combined with its orbital motion and the earth's rotation will enable these fixed photocells to scan the cloud cover over vast sections of the earth's sunlit surface. The data which will be recorded on the satellite's tape recorder will consist of a sequence of observations, each of which corresponds to the average light intensity coming from a small square-sectional area of the lower atmosphere and earth's surface. Since the size of each square section is from 6 to 30 miles on a side, the reconstructed picture will look like a mosaic in which large cloud formations, land and sea areas will be distinguishable.

(ii) *Radiation balance of the earth.*—Nearly all the energy incident upon the earth and its atmosphere consists of solar radiation shorter than 2.5 microns (about one ten-thousandth of an inch). Some of this radiation is diffusely reflected by clouds or the earth's surface at the same wavelength as the incident radiation. The remainder is absorbed by the earth which reradiates at a longer wavelength. The long-term balance of these three types of radiation (direct solar radiation, diffusely reflected solar radiation, and longwave earth radiation) is relatively uniform except for climatic changes. On a short-term basis, for example 24 hours, this balance may fluctuate. Data on this short-term balance is important to an understanding of weather phenomena.

An experiment prepared by the University of Wisconsin utilizes a tape recorder to record temperatures of four sensors at the ends of the antennas. Special surfaces and shielding arrangements make the sensors selectively sensitive to the type of radiations discussed above, thereby permitting calculation of the short-term radiation balance. Also, since these temperatures will be recorded as the satellite passes over different parts of the earth at different times of the day, these data may be of value for studies of the general circulation of the atmosphere.

Earth's magnetic field

By means of a satellite-borne magnetometer and ground station magnetometers located at the Minitrack sites, the Naval Research Laboratory hopes to obtain important information relating to the existence of the postulaed extraterrestrial ring current during the main phase of the worldwide magnetic disturbances or "storms." These disturbances could result either from the ring current or from ionospheric currents. Whereas both currents would subtract from the ground station reading, ionospheric current would increase any reading in a satellite located above the ionospheric current. The primary objective of the experiment is the investigation of the ring current, the secondary objective being the study of ionospheric currents. A third objective is to improve descriptions of the earth's main field.

Since cosmic rays are sensitive indicators of the earth's magnetic field, the cosmic ray experiment should also provide considerable geomagnetic information.

Radiation intensity

Dr. James A. Van Allen and his associates at the State University of Iowa have made a preliminary analysis of radiation intensities measured by single Geiger tubes carried by 1958 alpha and 1958 gamma. Although the counting rate in 1958 alpha was transmitted continuously, the data were recorded only when the satellite was quite near one of the 16 receiving stations. The data collected by 1958 gamma were also telemetered continuously. Pulses from the Geiger tube of amplitude greater than a certain threshold level were received by a scaling circuit. When 128 of them had been counted, the information was passed on as a single pulse at a maximum rate of 1 per second to a small magnetic tape recorder which stored the data obtained during each complete orbit. As the satellite passed near one of the receiving stations, a radioed command, or "interrogation," caused the data to be transmitted.

The interrogation signal activates a relay system which turns on the high-power transmitter and releases the magnetic tape. Within 5 seconds the information is read off the tape, telemetered, and the tape erased. Upon completion of the cycle the relays are reset, the transmitter turned off, the tape rewound, and the next recording begun.

At the altitudes below about 1,000 kilometers, the cosmic-ray counting rate agreed with extrapolations from similar data gathered on rocket flights. Above 1,100 kilometers, very high counting rates were obtained.

The very high rates (at least 35,000 counts per second) were not observed directly but were deduced from the behavior of the Geiger tube. At times, the Geiger tube indicated no counts. Examination of a typical command readout from 1958 gamma obtained from a pass ending near San Diego on March 28 at 1748 UT shows that the counting rates within the operating range of the counter occur near the two ends of the pass. The rates rise for long intervals, however, to values transmitted as 128 counts per second, the maximum rate capacity of the data-storage system, as described above. A section where the counting rate is indicated as zero is interpreted by Van Allen and his associates, G. H. Ludwig, E. C. Ray, and C. E. McIlwain, as being due not to equipment malfunction but rather to a blanking of the Geiger tube by an intense radiation field that causes the Geiger tube pulse amplitudes to fall below the necessary threshold value. Thus, this typical record represents a counting rate which, from a value at time zero, climbs quickly and probably smoothly to a very high level lasting through the 20- to 35-minute "dead time" interval. Then, before falling to a counting rate less than 128 counts per second, it drops, presumably in a smooth way, during a time interval of some 50 minutes during which the data-handling system records the maximum rate possible.

By exposing a counting unit identical to that carried in 1958 alpha to an X-ray beam, it was determined that at very high radiation fluxes the Geiger tube puts out pulses of such small height that they are below the threshold of the counting circuit. Thus, the counting rate as registered by the counting circuit is zero. This accounts for the dead time observed. This happens when the radiation intensity reaches a value which should produce 35,000 counts a second from the Gieger tube.

An ion chamber placed in an X-ray beam generating the minimum flux needed to reduce the counting rate to zero measured an intensity of 60 milliroentgens per hour. The X-rays used for this measurement had energies in the 50–90 kev range. Ionization produced by X-rays of different energies or by charged particles producing the same effect on the Geiger tube, would, of course, differ from this measurement.

The satellites carried no equipment which could determine the nature of the intense radiation, but it is presumed to be caused by either protons or electrons. If electrons, the radiation detected by the Geiger tube is probably X-ray produced in the satellite shell by the high-energy electrons which impinge upon it. (This type of X-radiation is termed "bremsstrahlung," literally "the deceleration or braking radiation.")

Similar radiation created in the atmosphere of auroral latitudes has been detected in rocket experiments conducted by Van Allen at altitudes up to 97 kilometers and by Anderson and Winckler and Peterson, at much lower altitudes by means of balloon-borne equipment. The relationship of the data obtained by these various means remains to be explored and should be a fruitful area of investigation.

The data from 1958 alpha were obtained mostly during the first 2 weeks in February. Data from 1958 gamma were obtained during the last 4 days of March. Van Allen has emphasized the preliminary nature of the report. The data analyzed represent only a portion of the total available data, which will be analyzed and reported on at a later date.

Van Allen also states that the observed high levels of radiation suggest these geophysical consequences: (*a*) Since it is unlikely that the individual particles could each have sufficiently high energy to penetrate through the geomagnetic field to such low altitudes, they must be at least initially associated with "plasmas," which perturb the magnetic field and are presumably related to geomagnetic storms and auroras. (*b*) Quantitative estimates suggest that the energy lost by the detected radiation to the residual atmosphere at altitudes above 1,000 kilometers may contribute significantly to the heating of the high atmosphere. (*c*) This high level has obvious biological implications, although our present knowledge allows only speculative ideas.

Optical tracking results

Preliminary analysis of the data obtained by visual observations and precise photographic observations is contained in a report by Drs. G. F. Schilling, Charles E. Whitney, Theodore E. Sterne, and Luigi G. Jacchia. This analysis has supplied information on the spin of 1958 alpha, on air density at very high altitudes, and on the expected lifetime of 1958 Alpha.

Dr. Charles E. Whitney found that 1958 Alpha, which was given a spin about its long axis during launching, now appears to rotate about its short axis, propeller-like. This conclusion is based on an observed variation of atmospheric drag and confirms a similar conclusion based upon the nature of the received radio signal.

Dr. Theodore E. Sterne has developed a simplified formula for computing the air density at very high altitudes from the motion of artificial satellites. This formula, applied to orbital data inferred by Whitney through a critical study of visual and radio observations of 1958 Alpha, gives an air density value of about 1.5×10^{-14} gm/cm^3 at an altitude of 368 kilometers (229 miles). A cubic mile of air of this density would weigh only 2 ounces. Nevertheless, the density is about 14 times greater than that predicted in 1956 by R. A. Minzer and W. S. Ripley of the Air Force Cambridge Research Center.

Dr. Luigi G. Jacchia, using a formula developed by D. C. M. Leslie, estimates that 1958 Alpha will fall toward the end of 1962.

Orbital determinations

Dr. Joseph W. Siry, of the Naval Research Laboratory, in a May 1, 1958, report states that the effect of atmospheric drag on the orbit of 1958 Alpha has been difficult to predict due to the fact that the drag force depends so strongly upon the angle of attack in the case of a cylindrical satellite of large fineness ratio such as 1958 Alpha. The orientation of the satellite as a function of time has been difficult to predict at times, thus making the prediction of the orbit correspondingly difficult. However, preliminary estimates by NRL indicate that the lifetime of 1958 Alpha will be about 5 to 10 years and that the atmospheric density in the neighborhood of perigee at about 370 kilometers (230 miles) is approximately 10^{-14} gms/cu cm. This is an order of magnitude greater than the value predicted for this altitude in 1956 by Minzer and Ripley.

Temperature measurements

Dr. A. R. Hibbs and Mrs. E. P. Buwalda, of the California Institute of Technology Jet Propulsion Laboratory, are authors of a report on a passive solution of space temperature problems and on temperature measurements made by 1958 Alpha.

Internal temperatures ranged from 0° C. to 35° C. inside the cylinder and from 5° C. to 40° C. inside the nose cone. Shell temperatures ranging from —25° C. to 75° C. were recorded.

The temperature control mechanism consists of a series of aluminum oxide stripes covering approximately 25 percent of the outer surface of the instrument package. By both reflecting and reradiating heat received by radiation from the sun and the earth, this coating was able to maintain interior temperatures well within the range needed to protect instrumentation from damage by heat or cold. The experiment was designed only to study the problem of instrument environment in a very small enclosure. However, it was noted that this technique provided temperatures in space within the range of human survival and that, with more elaborate techniques, the inner temperature of a larger space vehicle could easily be controlled within a narrower range of variation.

Micrometeorite densities

The flux of micrometeors in the satellites' orbits has been investigated by Drs. Edward Manring and Maurice Dubin of the Air Force Cambridge Research Center.

Two micrometeorite detection systems are used. One, called the gage detector, is carried on both 1958 alpha and 1958 gamma. The individual gages are 1 square centimeter in area and are wound with 2 layers of enameled wire 17 microns in diameter. Twelve of these gages, covering an area of 2 square inches, are mounted in circular pattern flush with the surface of the satellite's midsection. When a micrometeorite of 5 to 10 microns in diameter and traveling at meteor velocities, on the order of 25,000 miles per hour, smashes into one of the gages, the continuous circuit breaks and changes the transmitted signal.

The second detector, flown only on 1958 alpha, consists of a crystal microphone mounted against the skin of the satellite and connected to an amplifier. When the satellite is struck by a solid particle, the impact pressure is converted into an electrical signal which is transmitted to the monitor stations.

About 10 percent of the microphone data and 50 percent of the gage data from 1958 alpha are available for study. Seven hits have been detected by the microphone, but after 32 days of flight only 1 gage had registered an impact.

This data indicates that the average influx of particles 10 microns in diameter or greater was not more than $10^{-8}/m^2/sec$ during the period of observation, and that the average influx of particles 4 or more microns in diameter was about $10^{-3}/m^2/sec$.

RESULTS OF 1957 ALPHA AND 1957 BETA

A May 19, 1958, U. S. S. R. press announcement indicates that Soviet air density determinations based upon observations of 1957 alpha and 1957 beta are in substantial agreement with results obtained in this country. The Soviet determinations indicate that air density at 141 to 143 miles is about 5 to 10 times greater than the values of density at these altitudes indicated in a number of models of the atmosphere built on the basis of rocket measurements prior to the launching of the sputniks.

Many other interesting results are given and portions of the announcement are quoted below:

"*Atmospheric density and temperature*

"Inasmuch as the main action of the atmosphere occurs in the perigee area of the orbit, the change of its position leads to a change in the value of deceleration. This makes it possible to estimate the value of the changes in the state of the atmosphere depending on the latitude and time of day.

"Calculations to determine the density of the atmosphere, taking into account the changes in the location of the perigee of the orbit, were made on the basis of observations of the first sputniks. The calculations showed that the product of the density and the square root of the 'height of uniform atmosphere' increases as the orbit passes from the night side of the atmosphere to the day side and reaches its maximum at noon. An analysis of deceleration also revealed a decline of this value during the passage from the more northerly regions into those of the equator. Mention should also be made of the fact that there is good coincidence in the values of densities calculated on the basis of observation of Sputniks I and II and the carrier rocket of Sputnik I.

"The data obtained provide grounds for the conclusion that the temperature of the atmosphere at altitudes around 225 kilometers is higher than was formerly supposed on the basis of theoretical considerations. The discovery of higher temperatures of the atmosphere confronts geophysicists with the problem of the powerful sources of energy which heat the atmosphere. The known ultraviolet and X-ray radiation of the sun is hardly sufficient for that. At present only various hypotheses can be advanced. It may be assumed, for example, that the upper atmosphere in the Arctic regions is intensively heated by solar radiation of minute particles. It is possible that in general the entire upper atmosphere is additionally heated by infrasound waves coming from the troposphere or by electric currents arising in the electrically conductive ionized air as a result of its movement in the earth's magnetic field.

"Continued study of the upper atmosphere with the help of rockets and sputniks will enable scientists to get the final answer to all these interesting and important questions.

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"Results of ionospheric exploration

"Observation of the radio signals from the first sputniks has yielded new data on the outer ionosphere, i. e., its regions starting at 300 to 400 kilometers above the earth. The ionosphere is the upper part of the atmosphere and contains a considerable quantity of free-charged particles (electrons and ions). Radio waves passing through the ionosphere are reflected, are partially or completely absorbed and their courses deflected. That is why radio methods have become the most effective means of exploring the upper strata of the atmosphere.

"One of the basic parameters characterizing the condition of the ionosphere is the magnitude of electron concentration, i. e., the content of free electrons in 1 cubic centimeter.[1] Until now electron concentration was measured from the lower strata of the ionosphere to an altitude of 300 to 400 kilometers, where electron concentration has its so-called chief maximum.

"These measurements were made mainly by ground ionosphere stations emitting short impulse radio signals of varied frequency and receiving their reflections from separate strata of the ionosphere.

"As a result of regular measurements it has been established that the height of the chief maximum of the ionosphere and its electron concentration change from day to night, season to season, north to south, and from east to west. The greatest electron concentration observed over middle latitudes reached 2 million to 3 million electrons in a cubic centimeter, with electron concentration increasing at an average of 10 to 15 times from an altitude of 100 to 110 kilometers to an altitude of 300 to 400 kilometers.

"The data obtained from observation of the radio signals from the first sputniks make it possible to consider that electron concentration in the outer ionosphere (above the chief maximum) decreases with the rise of altitude 5 to 6 times slower than it increases below the maximum. Thus, from an altitude of 100 kilometers to an altitude of 300 kilometers the electron concentration mounted during the period of observation (in October) approximately tenfold, and from an altitude of 300 kilometers to 500 kilometers it dropped by half."

ADVANTAGES OF SATELLITE EXPERIMENTS

Dr. PORTER. The satellite unlike oceanography needs no definition here today. I think you all know what a satellite is from previous testimony that I have given before this group, together with illustrations and equations, but let me remind you today what the satellite can do. It can get data over a long time; it can get data over a large part of the earth's surface frequently, and it can get data at high altitudes above the more dense portions of the earth's atmosphere for a long time, over a large part of the earth's surface. These are the three characteristics of the satellite which enable it to do things no other experimental vehicle or no other technique in the IGY can do. But as against this, it is unquestionably the most expensive part of the IGY, although I think perhaps not the most expensive per unit of the data obtained.

Mr. THOMAS. May I interrupt you at that point? I was wondering if Dr. Price or Dr. Wexler were going to talk on the weather problems using your instruments here and your calculations?

Dr. PORTER. Yes, sir.

Mr. THOMAS. Dr. Price did not go into that, but I thought maybe he would and maybe you intend to.

Dr. PORTER. I shall mention that.

We have just heard about a ton of data or more which has been received from the Arctic program, and although science is not measured either by the ton or by the mile, I should like to point out that in the satellites which have been fired so far by the United States in the IGY

[1] One cubic centimeter equals 0.06 cubic inch.

program the telemetered data consists of enough magnetic tape to reach completely around the earth at the equator. This is perhaps symbolic because the satellite data actually is something like a ribbon tying up all the rest of the IGY program together in a way that makes it self-consistent.

You have heard three of the speakers before today mention the satellite as a means and an important part of the matter of gathering data in our disciplines and this is indeed true.

ATMOSPHERIC AND IONOSPHERIC STRUCTURE

During the course of the IGY satellite flights among other things we expect the satellite to contribute in the following ways: It will help in the determination of air density and temperatures at high altitudes above 100 miles or more, and it will help to determine the variation of the air density and temperatures with altitude, latitude, longitude, and time. It also will help in the determination of the variation in, and the structure of, the ionosphere at a particular time, and of higher parts of the ionosphere—the upper part of the F portion of the ionosphere—which is obtainable in no other way. Also, hopefully it may give us some information about anomalies in the earth's gravitation, although, in order to do this, we must require the very utmost of accuracy in determining where the satellite is.

PARTICLES AND RADIATIONS

It would provide a means for mapping the primary cosmic radiation as a function of altitude, latitude, longitude, and time. It would provide a means for directly investigating this plasma of positively and negatively charged particles which Dr. Simpson has just told you about and which is believed to originate in the sun and to be trapped in the earth's magnetic field. It will provide a means for mapping the earth's magnetic field directly by means of magnetometer observations at altitudes considerably above the surface of the earth and, again, as a function of latitude, longitude, and time. Also, we could use it in a particularly useful way to determine the vertical gradation of the earth's magnetic field. This can be done over a margin of distances obtainable in no other way, except at a single point with a vertical sounding rocket. It will enable us to obtain time histories of the fluctuation of solar ultraviolet and solar radiation during solar flares because it can "wait around" for these important events to occur. At high altitudes sounding rockets cannot always do this because a rocket has to go up and come down within a few minutes. The satellite can wait until it comes over and is there in place and ready to receive and keep time histories of the ultraviolet and X-radiation. This, of course, cannot be determined from the ground because both of these types of radiation are completely absorbed at the upper level of the atmosphere.

It can help to determine the size and density of micrometeorites in the area outside the earth's atmosphere and can, since it stays there a long time, determine the variation and the density of different-sized micrometeorites as a function of time. This can also, perhaps, help us to determine whether the density of micrometeorites is affected by the earth's gravitational field in some way that we do not currently understand.

METEOROLOGICAL OBSERVATIONS

Now, going over to the meteorological problems, we expect IGY satellites to contribute in two significant ways. One by providing a means for measuring the cloud cover of the earth—not only measuring the cloud cover of the earth, but describing it down to details with dimensions equivalent to something like 6 miles over all the area of the earth between 35 degrees north and 35 degrees south latitude at least once every day.

The second way in which it will be used in the meteorological sense is by providing means to measure the energy which is received directly from the sun, the amount of that energy which is reflected by clouds and snow fields and other bright objects, the amount of energy which is reradiated by the earth.

These 3 components of energy can be measured directly by a satellite over an area of the earth's surface of something like 60 miles, and this 60-mile area moves along under the satellite. Therefore, we can paint out strips 60 miles wide, and as it continues to pass over the earth's surface, we get this picture every day. The importance of this sort of measurement is hard to overemphasize.

The weather, as you all know, is basically a heat engine, an engine which receives its driving energy from the sun. This energy is dissipated ultimately through radiation, but in the course of being absorbed and reradiated it is carried by convection, both of the oceans and of the atmosphere, from the point at which it is received to the point at which it can best be radiated. It is these convection currents which produce the winds and the storms of the atmosphere, and quite conceivably also a considerable part of the storms and currents of the oceans.

ENGINEERING ADVANCES

Certainly not least among the contributions we expect from the satellite program are the engineering contributions which will result from the design of the thermal aspects of the satellite. These include: learning how to provide the kind of coatings which will give us the desired equilibrium and temperature under conditions where it receives energy from the sun and then reradiates energy back into space, the development of solar power supplies and long-lasting power supplies that will take energy directly from the sun and provide an output in the form of electric voltage and current to operate radio equipment and so forth, and the development of storage elements and tape recorders and other instruments. All of these will represent engineering contributions of considerable magnitude.

RADIATION ZONE DISCOVERY

I think rather than trying to go into all of these various contributions in detail, I would like to elaborate a little bit more on the results from these first two exploratory devices, Explorer I and III, and the way in which this produced what I consider to be a major breakthrough.

Dr. Simpson has already mentioned that the end result of this breakthrough was the discovery at considerably lower altitudes than

had been thought probable before of a cloud or plasma of electrically charged particles. The experiment was not intended to measure this sort of thing at all. It was intended to be a cosmic ray experiment. The instrumentation was designed to measure cosmic ray counts on the order of 30 or 40 per second average, and it was given enough factor of safety to measure up to about 128 counts per second. Actually at low altitudes it did measure cosmic radiation just about as had been expected by extrapolating the results of surveys. However, as the satellite went through the region of about 1,000 to 1,200 kilometers, or about 600 to 700 miles altitude, over the latitudes of the United States, a very abrupt increase in the count was observed.

Actually, what happened was that we went up to about 128 counts per second and saturated the counting equipment. The number of counts was so high that it actually saturated the Geiger tube which counts the particles themselves so that the number of counts dropped to zero. It was overloading the tube to the extent that the pulses out of the tube were not great enough to trigger the counter at all. By putting this tube actually in a laboratory setup designed to measure the effect of X-rays on it, we have since determined that the Geiger tube begins to saturate at about 15,000 counts per second but that there must be in excess of 35,000 counts per second in order to produce this complete saturation effect. This, of course, was completely unexpected at these altitudes.

ORIGIN OF RADIATION

In trying to decide exactly what this sudden rise in count represented, Dr. Van Allen who was the experimenter responsible for this particular project, came to the following reasoning. He concluded that this type of radiation could not possibly represent direct rays from the sun because if it were radiation of this intensity and magnitude and energy, it would surely penetrate down to the lower altitudes and would not cut off abruptly at 1,000 kilometers.

The satellites carried no equipment which could determine the nature of the intense radiation, but it is presumed to be caused by either protons or electrons. If electrons, the radiation detected by the Geiger tube is probably X-rays produced in the satellite shell by the high-energy electrons which impinge upon it. This type of X-radiation is termed "bremsstrahlung," literally "the deceleration or braking radiation."

Similar radiation created in the atmosphere, of auroral latitudes has been detected in rocket experiments conducted by Van Allen at altitudes up to 97 kilometers and by Anderson and Winckler and Peterson, at much lower altitudes by means of balloonborne equipment. The relationship of the data obtained by these various means remains to be explored and should be a fruitful area of investigation.

IMPORTANCE OF THE DISCOVERY

Scientifically, this discovery begins to tie together a great many things we had not tied together very well before. As Dr. Simpson indicated, when an electron, or any other charged particle, enters a

magnetic field, its path is bent. If I take a charged particle coming into a magnetic field from this direction it will tend to be bent around the field, but it will tend to continue to travel in a spiral in the field. This spiral, for particles of this energy, is not very large—a matter of a hundred meters at most in diameter. Consequently, it will tend to travel among the lines of magnetic field in a corkscrew fashion, but as the magnetic field tends to converge we get something like the equivalent of a back pressure. Pressure tends to build up because the particles are being drawn closer together into tighter spirals, so they will be reflected and tend to travel back in a corkscrew fashion and be reflected again, and they will travel along these tubes of magnetic force many, many times before they are removed from the plasma.

RUSSIAN SATELLITES

Dr. PORTER. I think that I should not close this part of the discussion without a word or two about the Russian satellites. The Russian satellites have been useful to use in two major ways. They transmit radio waves and therefore they are valuable as tools in the field of ionospheric research. The radio waves from the Russian satellites can be used to determine the ion densities by the amount of bending and refraction, providing we can determine where the satellite is, and by using our tracking networks, both radio and optical, we have been able to determine fairly well where the Russian satellites are.

Unfortunately, we were not ready for the first two and did not do as good a job as we could have done had we known when we could expect them. This third satellite we have been expecting for a long time; consequently, we were rather well prepared for it in these respects. Unfortunately, the power of its radio transmission is considerably less than the power of the first two and it makes the work a little more difficult; nevertheless, I am told we will get quite useful results from it as far as the ionosphere is concerned.

INTERNAL INSTRUMENTATION

With respect to the internal instrumentation, we have translated the descriptions that have been published of this satellite in Pravda and elsewhere, and I would like to say for the record that I am tremendously impressed by the sophistication and advance of the instrumentation which it contains.

Mr. YATES. Advance over what?

Dr. PORTER. Over the present state of our ability through satellite experiments. In some areas they are now doing experiments which we are talking about doing a year or more from now. I will mention specifically the magnetic and ionization manometers, the devices for measuring directly the density of the atmosphere by means of internal instrumentation rather than by the external effect on the satellite itself. Also, their mass spectrometer, flux meter, and ion traps. Each of these represents a type of instrument that we will not be able to carry during the present IGY program.

In other areas their instrumentation is similar to ours. Notable for its absence in any of the satellites so far has been anything relating to the field of meteorology. So there are some pluses and some mi-

nuses; nevertheless, I think that we should view with some concern the extent to which they have been able to go already in the field of satellite research—concerned only, of course, if we consider that we must, as a nation, make a contribution scientifically which is absolutely first rate. We certainly shoudl look on it with pleasure so far as their contribution to world science is concerned.

SUMMARY OF PROGRAM

In conclusion, I think that I can say with considerable confidence that the program of the earth satellites in the IGY is progressing at least as well as has been anticipated at the beginning of the program. We look forward to considerably better success in the future with the Vanguards than we have had in the past.

Mr. YATES. We join with you.

Dr. PORTER. And we have great plans for using the successful Vanguards we know will come within the months ahead.

We feel very fortunate that the Explorers were available when they were and that we were in a position to instrument them carefully. I think we can take some pride in the fact, although we have neither put up the first nor the biggest satellites in this country, we have, I think, contributed the first really scientifically instrumented satellite to remain in operation for a long enough period to be really useful. The second Soviet satellite was indeed a useful experiment but the fact that it lasted only a week certainly has diminished its value as far as science is concerned.

I share Dr. Tuve's feelings completely with respect to his appreciation for the support that we have had in this whole program, especially from the Department of Defense, who have indeed made the program possible, and to this committee, which has been so generous with support at a time when it really counted.

Mr. YATES. Thank you, Dr. Porter. Your prepared statement has a very good comparison between the sputniks and the Explorers and Vanguard I.

Dr. PORTER. Thank you.

STATUS OF SATELLITE DEVELOPMENTS

Mr. YATES. Having read your statement, and having tried to appraise the comparisons between the Russians' efforts and our own, I must commend you for your objective and dispassionate presentation. I am concerned, with you, with what was contained in Sputnik III when you recited in your scientific manner the instruments that were contained in Sputnik III. You state they were very sophisticated, and I am concerned by the fact you say none of the vehicles which will be projected into orbit during the IGY will contain instrumentation comparable. Are we that far behind the Russians in these fields?

Dr. PORTER. I do not think that we can avoid answering yes. It has to be a qualified yes, of course. If we had not chosen to do some of the things we are going to do in the IGY, we could have carried some of the instruments that are being carried in their satellite.

Mr. YATES. Your description of these instruments as such does not make an impression on me because I do not know what they do. Can

you tell us the nature of these instruments and why they give you concern so that we can appreciate fully the reasons for your concern?

Dr. PORTER. Let us take the mass spectrometer. We have very good mass spectrometers in this country, probably as good as anywhere in the world for use in high altitude rockets. However, the weight of these instruments is such that they cannot be carried in any of the types of satellites which are now laid on for the IGY. Unquestionably, they can be carried in satellites that will come after the IGY.

ATMOSPHERIC COMPOSITION

Mr. YATES. What does a mass spectrometer do?

Dr. PORTER. The mass spectrometer is used for analyzing the composition of the atmosphere at high altitudes. An instrument very similar to this can be used for measuring the density of the atmosphere directly. An experiment of this sort, however, is not easy to design because one must be very much concerned with the problem of outgassing, that is, the problem of entrainment of air or other gases by the satellite itself. And in order to make such an experimental instrument really useful, one must design not only the instrument itself, but the whole satellite in such a way that we will avoid undue presence of gases which are not actually existent in the atmosphere at these high altitudes.

The electrostatic flux meters, as nearly as we can tell from the descriptions, are of relatively conventional design.

However, we do not have any ready to go into satellites today. We have been considering them for future satellites after the IGY, but we do not have any planned for the present IGY satellites.

The positive-ion traps seem, to me, to be a very ingenious design, and, again, we have none comparable to them today for carrying in the satellites.

ION TRAPS

Mr. YATES. What is an ion trap—some device that traps an ion?

Dr. PORTER. Exactly.

Mr. YATES. Sort of like flypaper?

Dr. PORTER. They consist, actually, of mesh spheres with a central electrode at a different potential, so that, when positive ions come through the mesh and are subjected to an electric field inside the mesh sphere, they will be collected on the inner electrode, and the amount of current registered by that electrode—very minute, of course—will represent the number of electrons which have penetrated the wire mesh. Here, again, the device itself does not appear to be particularly complicated; however, they have provided very good means for insuring that this interspace is swept out periodically so as to collect the new, clean sample, and a number of other experimental tricks that impress one as resulting from very careful thought and experimentation in the laboratory.

Their work on instrumentation for measuring very low pressures has always been very good, indeed, and we would expect that the instruments which go under the heading here of magnetic and ionization manometers (which, in effect, measure the presence of very small numbers of gas particles by producing ionization and collecting the number of ionized particles then present) will be very useful instru-

ments. None of these is now ready in a size and in a state of development that would be suitable for our present IGY program. Some of them are ready, such as the mass spectrometer, but they are too heavy to carry in our IGY satellites. Perhaps they could be carried in IGY satellites if we did not carry something else, but they are not yet, for one reason or another, at a stage of development where we can put them in.

Mr. YATES. Do I understand, from your response to one of my questions about measuring the quantity of mass, that this could be used for topographical measurements as the satellite went around the earth? Does it discharge beams which reflect the measurements from the surface of the earth?

Dr. PORTER. In discussing the Russian satellites, I did not intend to give any such indication; no.

Mr. YATES. It does not have such an instrument?

Dr. PORTER. As far as we have been told, it does not have such an instrument. I think that, in one of their interviews that was given by some of their scientists to the press, there was a definite statement made that they did not have any such device. However, it does not need such a device to impress one, scientifically.

SATELLITE LAUNCHING

Mr. YATES. According to the U. S. News & World Report, the rocket that launched Sputnik III could fire a missile 6,000 miles, thereby enabling it to reach any part of the United States from the Soviet Union. Is that correct?

Dr. PORTER. That would depend somewhat, sir, upon the payload to be carried that distance, but I think that a rocket which would launch a satellite of this size would certainly be said to be comparable with our own ICBM rockets, because Dr. York, over at the Advance Research Projects Agency, has indicated that our own ICBM could put satellites on the order of several tons into an orbit.

REACHING INTO SPACE

Mr. YATES. Dr. Simpson indicated that we were on the doorstep of going beyond the earth 500,000 miles. The best step that we have made toward that has been 1,700 miles with Vanguard.

Dr. PORTER. Actually, about 2,500 miles.

Mr. YATES. Can we attain any higher distance than that in the foreseeable future?

Dr. PORTER. Yes. I think it has been announced that some five attempts will be made to project a small scientific payload to a distance of the moon during the present fiscal year.

Mr. YATES. Which is how far?

Dr. PORTER. The moon is about 240,000 miles from the earth.

Mr. YATES. Are there any countries that are shooting satellites in this IGY, other than Russia and the United States?

Dr. PORTER. No other nations have indicated any intention to launch satellites during IGY. A number of the other nations are launching rockets.

Mr. YATES. Have any of these satellites gone beyond the earth's magnetic field?

Dr. PORTER. No; definitely not. The earth's magnetic field extends out for many times the earth's radius, and we have only gone to something about half the earth's radius.

Mr. YATES. Thank you, Dr. Porter.

The committee will stand in recess until 10 o'clock tomorrow morning.

TUESDAY, JUNE 3, 1958.

Mr. THOMAS. Gentlemen, will the committee please come to order?

Yesterday was perhaps one of the most profitable days this committee has spent in many, many years. We thoroughly enjoyed having these distinguished scientists before us. We will continue this morning.

Dr. Kaplan, who will you call on next, and what will be his subject?

IGY PROGRAMS IN AURORA AND AIRGLOW

Dr. KAPLAN. I would like to call on Norman J. Oliver, vice chairman, USNC Technical Panel on Aurora and Airglow, Chief, Ionospheric Physics Section, Geophysics Research Directorate, Air Force Cambridge Research Center.

Mr. THOMAS. We are delighted to have you, Mr. Oliver. We have been looking forward to your statement. Just carry on in your own way and for as long as you like.

We will insert Mr. Oliver's statement at this point in the record.

(The statement referred to follows:)

IGY AURORA AND AIRGLOW PROGRAM

AURORAL OBSERVATIONS

A worldwide comprehensive auroral observation program in 49 countries is underway for the first time during the IGY. Many of these 49 countries are in low latitudes where auroras are seldom seen. Nevertheless, in all of them, auroral reporters have been appointed to collect reports of visual observations in the event that a very great aurora should occur. A number of such auroras have been reported in the last century, but these events of great scientific importance have usually been inadequately described. One hundred and forty-two camera and instrumental auroral observation stations, as well as extensive amateur visual observing programs, have been organized in 17 countries.

The 39 stations and hundreds of amateurs participating in the United States program have already had much to observe. The fact that the IGY was scheduled for a period of expected maximum solar activity has greatly enhanced the value of the program, for already a number of the largest solar flares (class 3 plus) have resulted in extensive auroral displays. These are observed synoptically by all-sky camera stations and visual observers whose reported data are charted and compared. Synoptic maps are in preparation describing the location of every aurora reported over the North American Continent at 15-minute intervals. This is the first time that such a complete description of auroral data has been assembled for the use of geophysicists studying auroral and such related phenomena as ionospheric and geomagnetic effects.

Visual and all-sky camera observations

The reduction of data received from all-sky camera stations, from the 700 volunteer observers, and from 120 cooperating weather bureau observers necessarily lags the collection of the data by some months, but it is interesting to note that, corresponding to the unprecedented solar activity of the IGY period, auroral displays have been exceedingly numerous. The IGY was ushered in, most appropriately, by a spectacular aurora on the night of June 30–July 1 which was observed by many residents in the Northern United States to extend from the northern horizon across the zenith and down to within a few degrees of the

southern horizon. This activity was, presumably, the effect of a solar flare observed on June 28 by an observatory near Moscow. Nevertheless, subsequent experience has shown that predictions of auroras based on the more outstanding solar phenomena are not wholly reliable. From the IGY results should come a more precise delineation of the solar-auroral relationship.

Considering that the average observer sees not more than a few auroras per year even during periods of maximum solar activity, it is interesting to note the numbers reported from somewhere in the United States during the first several months of the IGY. In July of 1957 displays were reported for 12 days during the month, there were 19 auroral days in August, and reports were submitted for 20 and 11 days during September and October, respectively. These frequencies will prove useful in checking the suggestion that auroral activity should be greatest at the time of the equinoxes since then the earth is more directly in line with the most active effective areas of the sun.

An intriguing discovery has been made from Antarctic and Arctic observations at Wilkes station and Thule, Greenland. Quiet homogeneous auroral arcs are usually seen lying parallel to a circle of geomagnetic latitude, sometimes extending several hundred miles around the earth. But at these stations such forms have been observed that appear to be oriented in the north-south direction rather than along the geomagnetic latitude parallel. The significance of these phenomena is not known.

Outstanding displays

The larger the auroral display the lower the geomagnetic latitude at which it is observed. By this criterion as well as the visual importance of the display, the significance of the display can be judged. Two examples are particularly notable. The displays of September 22–23, 1957, and February 10–11, 1958, were seen as far south as Cuba. The former was seen in every State in the Union and Alaska as well as Cuba. The latter was the most carefully observed one ever recorded in the world. More than 2,000 reports of it were received by the United States auroral center. Reports from ships at sea show that it extended in an east-west direction for at least 6,000 miles and probably farther (European reports are not in yet). Both these auroras and a display on November 6–7, 1957, were of the rare red variety which generally extend to very high altitudes. Indeed, the red glow portion of the February 10–11 aurora extended from 150 to 600 miles, although the green arcs were apparently at the 60-mile level, as usual.

The great February aurora has been described as being red, actually, it was multicolored with the red forms occurring adjacent to green and white ones. Spectra taken in Alaska showed unusually strong development of infrequently noted emission lines. It occurred following a period of strong solar radio emission activity, and was accompanied by strong magnetic and unusual earth current effects. (It has been rather firmly established that if an aurora occurs at the zenith over a given location the magnetic disturbance at that location is a maximum.) The effect on earth currents is exemplified by the fact that the potential on the transatlantic telephone cable from Newfoundland to Scotland reached a maximum of 2,650 volts at the western end in the evening of February 10. Lesser effects were observed on a cable from Washington to Alaska; none at all were seen on a cable from California to Hawaii. Finally, in addition to these associated phenomena strong bursts of X-rays, probably the result of high-speed electrons impinging on the atmosphere, were observed on cosmic ray balloon flights from Minneapolis.

Spectroscopic observations

The preceding discussion has been concerned primarily with some results of the visual and camera observing programs carried out in the IGY. A no less significant portion of the IGY program is devoted to observing the spectral characteristics and variability of auroras through use of patrol spectographs and scanning spectrometers. It has already been noted that the spectral characteristics of the February 10 aurora were unusual; other spectral results of an unusual nature most certainly will develop. However, the reduction and analysis of spectra is a difficult and intricate task. Consequently, the more significant discoveries will only be made after the considerable time needed to analyze the data has elapsed. The information gained should be instrumental in furthering the precise theoretical explanation of how incoming protons and electrons excite the earth's atmosphere to emit auroral light.

Radio observations

Bombardment of the atmosphere by charged particles from the sun causing auroras can be expected to result in effects observable by other than optical means. Two observed by radio means during the IGY are the resulting ionization detected by radio and radar echoes and the enhanced ionospheric absorption detected by the monitoring of cosmic noise sources through the ionosphere. Radio auroral studies at a rather low geomagnetic latitude (43°) have shown that the auroral ionization responsible for radar reflections may be formed at heights considerably in excess of 60 miles, i. e., above the lower limit of the visual aurora. On the basis of radar as well as some substantiating visual IGY data it can now be said that auroral displays tend to occur on the same days in both northern and southern polar regions. It is most probable that there is effective simultaneity of such displays, but firm knowledge of this must await a complete examination of the experimental results which have only recently been received from the Antarctic.

Although scaling of cosmic noise absorption data obtained through a joint auroral-ionospheric program has not yet been effected some interesting qualitative observations have been made. Observations in Alaska show a generally progressive decrease in absorption at stations located successively south geomagnetically from College, Alaska. Nighttime absorption is less than daytime absorption and is strongly correlated with geomagnetic disturbance periods. However, the southernmost station observed no nighttime absorption during the fall of 1957. On the other hand, day and night absorption is often extremely intense at College. Thus, the data delineate an auroral absorption zone, and confirm that nighttime absorption is definitely associated with visual auroral activity. In general, the greatest nighttime absorption comes during the breakup and the postbreakup phases of the auroral displays. It should be noted that strong auroral absorption effects were observed in connection with the February 10 aurora.

METEOR OBSERVATIONS

A report from an earlier Antarctic expedition had indicated that the rate at which small meteors can be observed visually in the Antarctic was larger by a factor of the order of about 10, than the rate at United States latitudes. This result could presumably be explained in either of two ways: (1) the earth may scoop up more meteoric material in the South Polar regions, or (2) seeing conditions may be better there. Since, if the first explanation is correct a meteor-detecting radar should be able to detect the effect, such an instrument was installed at Little America under the aurora program and results have now been reported. They indicate that the meteor echo rate was consistent with expectations based on temperate-latitude measurements, and that the meteor-detection rate did not change drastically at any time during the observation period April-July 1957. However, observations will continue.

AIRGLOW OBSERVATIONS

Finally, airglow observations are an essential part of the IGY investigations of light emitted in the high atmosphere. The airglow supplies much of the light of the night sky, and is being observed at three important wavelengths from a longitude chain of stations at which instruments scan the whole sky successively in different directions. The data are placed on punchcards and fed into a computer from which, after a number of corrections, overall sky charts of airglow intensity emerge. Data from a spectral line emitted by oxygen show pronounced patchiness; discrete "blobs" actively emitting the oxygen line seem to wander through the sky with an apparent velocity of 150 miles per hour. In general, the size of the large airglow features are of the order of 600 miles, while the temporal variations seem to span several hours. Further, at a station in Colorado it has been found that the airglow is brighter to the north in summer and winter, but brighter to the south in spring and autumn. These studies show that the airglow, originally thought of as a quiescent glow in the earth's atmosphere, is quite complex with dramatic temporal and spatial variations. Their physical significance is not yet understood, but these effects will be investigated with relation to other high atmospheric phenomena to understand their essential nature.

Mr. OLIVER. Thank you very much. It is a pleasure to speak before this group.

I thought before I made note of some of the accomplishments during the IGY I might present some background on the aurora itself. We take it for granted that everyone knows where the auroras are, and this is not always the case.

ORIGIN OF AURORA

Aurora actually is the only visual manifestation of incoming particles from the sun. I am not saying we see the particles immediately after they leave the sun, but certainly the origin of the radiation of the aurora is due to solar particles.

This diagram indicates that the auroral zone where the maximum number of auroras occur, as normally indicated, is an area about 22° from the geomagnetic pole. The auroral zone is concentric with the geomagnetic axis. The particles, insofar as the mechanism of the sun is involved, are ejected and then they travel through space in some manner such as this shown on the diagram.

This stream of particles sweeps out into planetary space, and eventually it reaches the earth. Sometimes these particles are rather discrete in their energy range.

On the scale of this blackboard the relation of the size of the earth to the sun is as shown by that little mark I have at the bottom, so you see this is not drawn to scale any more than Dr. Simpson's 93 million miles was drawn to scale.

Because of this the earth is enveloped instantaneously by this strong stream, a dense stream, and the magnetic storm starts within 30 seconds all over the earth. This is what happened to us on February 10, as an example, in that very spectacular aurora which was connected with a sudden commencement or magnetic disturbance.

In general, auroras are not caused by the sudden commencements but they increase gradually. Magnetic variations on the surface of the earth are not instantaneous all over the globe. They are localized with the aurora. This is because the stream, not having a high density, has low densities at the center, and gradually peters out, and it may take the earth a couple days to pass through the solar stream.

INFLUENCE OF MAGNETIC FIELD

These particles in the solar stream to which I refer are particles consisting of protons and electrons which essentially give a neutral plasma, but the particles are charged.

As the particles enter the magnetic field of the earth, which extends through many earth radii, they are forced into the field lines, or as one of the theories presents it, they are trapped into what is known as a ring current, which is a ring of electrons and protons lying in the plane of the Equator at a distance of about 55 earth radii. This is one theory.

Then it is proposed that from this "bank" of electrons and protons the particles eventually are injected into the earth's atmosphere along the field lines. This is the most generally accepted theory.

Mr. YATES. What is a field line?

Mr. OLIVER. A line of magnetic force of the earth such as Dr. Simpson drew yesterday. IGY has caused us to do a lot of thinking about the aurora and the trapped electrons referred to yesterday, and about many theories, one being a theory which involves a ring current, and

another one which says that the energy to form an aurora may exist in the earth's atmosphere most of the time and all it needs is a little triggering. The sun ejects particles all of the time, not only when we see sunspots—low-energy ones and high-energy ones.

If the low-energy ones are trapped, and I refer now to protons and electrons, in these magnetic field lines, this could be one source of energy. I am sure we do not all see eye to eye on this trapping business because most of the calculations reveal the fact that if the electrons have low energies their lifetime in a trapped condition is quite short. If they have high energy, talking now in the million electron volt range, they should have longer lifetimes.

Every time these trapped electrons make a circuit from pole to pole (actually they do not get down to the earth but are trapped at high altitudes), they oscillate back and forth by reflection. They lose energy in two ways. One way they lose energy is by radiation. If they have high energies, they must radiate just by virtue of changing direction. In radiating they lose energy.

Also they collide with the atmospheric particles. One of the things which is an outcome of the IGY is the fact that the particle density at higher altitudes seems to be higher than we originally anticipated. How much higher I am not qualified to say, but it is higher than we anticipated. Therefore the energy again is lost by these incoming auroral particles, and eventually they come to lower altitudes and enter the atmosphere. Only a very small percentage of the particles from the sun can be trapped because they have to arrive at the proper angles to be trapped by the field lines.

AURORAL AND SOLAR EVENTS

We are certain, however, that a particular kind of large solar event always produces an aurora. We can say this almost without reservation. But all events on the sun which should produce auroras do not. In other words, we take the major disturbances and get a 1-to-1 correlation. If we take the lesser disturbances we do not get a 1-to-1 correlation, so the probability of some trapping actions certainly exists.

AURORAL LIGHT

Another very interesting thing is this: The mechanism is that the protons come down the earth field lines into the atmosphere, and collide with the atmospheric particles. At the higher altitudes the particles consist of molecular nitrogen, atomic nitrogen and only atomic oxygen. As the particles get lower in the atmosphere we have molecular oxygen as well as molecular nitrogen and some mixtures of both at some transition point perhaps above 120 kilometers or so.

These collisions cause the atoms to be excited and on their return from the excited state they produce radiation. The common radiation associated with aurora is a green radiation because the green comes from a forbidden atomic transition of oxygen which can take place at the pressures which are present at the altitudes of 100 to 120 kilometers or so; so the predominant radiation is green.

However, there is much more to the spectrum than just green radiation. There is a great deal of violet radiation which normally we do not see because it occurs just below the sensitivity of the eye, and this

is one of the most brilliant features of the aurora. Instrumentally it is extremely brilliant and it is one way by which we separate aurora from airglow.

The airglow spectrum, because it is excited in a different manner, does not produce the 3914A N^{+}_{2} bands. These are excited from electrical bands of nitrogen.

Dr. KAPLAN. You might define the term.

Mr. OLIVER. I will separate the two in a moment. I thought I would mention it in passing.

RED AURORAS

If for some reason these particles, certainly because they have lower energy than usual, do not get down to these altitudes, say 120 kilometers, but stay high in the atmosphere, they produce these rather rare red auroras, such as the spectacular one we referred to. This is because another atomic oxygen radiation can take place at reduced pressures, pressures lower than at 100 to 120 kilometers. This is produced as red radiation at 150 to 600 miles, which is right in the red region. This is what was produced during this last February 10 aurora.

The mystery is why do these electrons not have energy enough to penetrate the same as most of the other aurora storms. This is a darn good question. Dr. Simpson intimated yesterday, without saying so, that there might be particles coming from the sun which carry magnetic fields with them. They might set up magnetic barriers, not at the great distances he suggested for cosmic rays but they might set up other ones in the vicinity of the earth so there is a selective release of lower energy protons which do not have the necessary penetrating power to reach the 100-kilometer level.

This was essentially a red aurora. On the average it was a red aurora, extremely extensive. We generally estimate the intensity of an aurora on the basis of its extent, how far south the aurora goes. This is generally a fair index of how intense the storm was.

FEBRUARY 10 AURORA

This evidently was an extremely intense storm because it was observed as far south as Cuba and Mexico City, and yet the particles did not have enough energy to get down to the lower extremes of the atmosphere. Measurements made in Michigan and in Alaska indicated the lower edges were above 200 kilometers. This is just one of the great mysteries, but certainly no aurora was observed as carefully and as thoroughly as this February 10 aurora.

STATIONS AND INSTRUMENTATION

Forty-nine countries make auroral observations in the IGY. Many of these countries are at low latitudes but they were deliberately involved for just such instances.

Mr. THOMAS. What equipment do they use in making those measurements?

Mr. OLIVER. In the lower latitudes, except for our own program, mostly visual observations. At the lower latitudes we have a line of

instrumentation which goes all the way from Thule, within 6° of the geomagnetic pole, down to Peru. We have essentially complete coverage of the whole geomagnetic longitude line with electronic photometers, spectrographs of all types, and even radar down to certain latitudes.

APPLICATIONS OF SPECTRAL DATA

Mr. YATES. Will you tell us the difference between the aurora and the airglow?

Mr. OLIVER. The excitation of the particles in the earth's atmosphere and a spectral analysis of this spectrum gives us a great deal of information about the type of particle which is there, the kinetic temperature of the particle, and the process by which particles are formed.

This, as has been mentioned before in passing, has important applications to the propulsion problems, fuel-combustion problems. They are closely related. The fact that the particles on being excited have additional energy, causes one to ask how much energy might be extracted from this atmosphere; is there sufficient energy there to use for propulsion; is there sufficient energy there to use for other purposes such as making artificial flares, as has been demonstrated by perhaps the sodium experiment and where sodium has been injected into the atmosphere? This is a different process.

Mr. THOMAS. Spell the sodium experiment out.

Mr. OLIVER. I will do this with the airglow.

Mr. THOMAS. Go ahead.

Mr. OLIVER. So that all these things give us a great deal of information about the atmosphere and the energy content of the upper atmosphere.

ORIGIN AND NATURE OF AIRGLOW

In addition to the aurora we have a permanent airglow. This is a litte difficult to separate. We hear of the light of the night sky and the night airglow. The light of the night sky includes the night airglow because the light of the night sky is a summation of the light of the night airglow plus some radiation caused by cosmic rays coming in, and by the scattered light of the galaxy.

Two or three years ago I pointed out that the galaxy did actually introduce more background light into the spectrum of the night sky than had been hitherto supposed, which caused revision in the estimates of the heights of emission of the airglow.

The airglow is a more or less primitive feature of the earth's atmosphere. During the day the sun produces excitation mechanisms in the upper atmosphere. These mechanisms store energy during the day and at night this energy is released. The release of this energy results in a light which is extremely weak, very small, 1/100,000,000 candles per square centimeter, which is an extremely small amount of light. Normally it is not detectable with the eye.

However, on occasions when the sky is really black during the dark of the moon, and one is at a fairly high altitude, it is just barely discernible as a faint green light, just a little green blush in the sky.

THE SODIUM EXPERIMENT

The energy which is put in the atmosphere by the sun may be put to useful purposes, such as the excitation of sodium. The sodium exper-

iment simply consisted of sending a rocket to what we estimated to be a satisfactory height. This experiment was suggested by Dr. Kaplan many years ago, but had not been practical until we learned a lot more about rocket techniques.

The sodium was sent up in a vaporizer and at the proper altitude it was released into the earth's atmosphere, and immediately proceeded to glow and produced a very brilliant cloud of characteristic sodium light. You have seen the sodium lamps they use for street lighting. It was a cloud of this color which persisted for a considerable length of time.

This is useful in itself, but let us not consider sodium necessarily by itself but other chemicals, many other chemicals. This flare could be used to illuminate a large area on the ground perhaps.

UPPER ATMOSPHERE WINDS

In addition it provides a very neat way of measuring winds at these altitudes. The motion of this cloud and the dispersal of the cloud gives a good indication of how the winds are blowing and in what direction.

Though I am not one who is too familiar with winds at these altitudes, I would say there are very amazing things happening, such as within a few kilometers the wind would be going in opposite directions by tremendous rates of speed, as much as 150 miles an hour in different directions.

Mr. THOMAS. Who testified to that yesterday?

Dr. KAPLAN. Dr. Wexler told about such winds but at much lower strata.

Mr. THOMAS. What altitudes are you talking about?

Mr. OLIVER. About 60 miles. Dr. Wexler was talking about from 2 to 6 miles.

Dr. KAPLAN. That used to be high. It isn't any more.

Mr. THOMAS. Go ahead, Mr. Oliver.

CALIBRATION

Mr. OLIVER. The airglow program is perhaps one of our most finely developed programs in the IGY. The instruments are essentially calibrated from the same standard all over the world, and this is due to the great personal effort of Dr. Roach, who has the airglow program.

He personally has gone to Japan and calibrated an absolute photometer; he has gone to Australia, and did the same; he calibrated all of ours and the Canadian ones; and I understand he came back from Moscow and calibrated those in Russia; so we have an absolute standard all over the world.

I have not said this to Roach, but personally I think this is a marvelous thing that he has taken the effort to do this.

Dr. KAPLAN. Dr. Roach is in the same laboratory as Mr. Shapley, the Central Radio Propagation Laboratory, Bureau of Standards.

AIRGLOW MOVEMENTS

Mr. OLIVER. The airglow studies indicate that the ionization which is at these altitudes in the night airglow actually does move with certain patterns which are seasonal; they vary with latitude. The sizes of the ionization vary from a few kilometers perhaps to clouds 600 kilometers in extent, that is, 360 miles in extent, and they provide a great deal of information on circulation at these high altitudes.

AURORAL EFFECTS ON RADIO

To go back to the aurora, the aurora, besides producing visual radiation, has some very serious effects on communications. Because of this, and the associated magnetic disturbance which goes along with it, it is absolutely necessary that at some time in the not too distant future we be able to predict the occurrence of these auroras and the extent to which we expect them to go southward.

Any device which depends on magnetic indications for guidance is completely lost during one of these auroras. Any communications which have to go over the pole are completely lost during these auroras. In addition to this, there is not only the fact you lose the contact path, but it produces undesirable reflections of these signals.

AURORAL EFFECTS ON COMMUNICATIONS

There are three effects. One is the absorption of the energy which reduces the range of the radar; secondly, it produces a distance error because the radio wave passing through the ionized medium is retarded and, therefore, we get an inaccurate distance measurement of anything we are looking at. In addition, because of the refraction, we get a position error.

Part of the IGY aurora program consists of studies of the ionization of aurora. These are conducted with international cooperation all the way from Alaska around the United States, Canada, over into England, and into Scandinavian countries and into Russia.

Mr. THOMAS. Off the record.

(Discussion held off the record.)

RADIO ASTRONOMY

Mr. OLIVER. In the IGY program we have not ignored the radio astronomy techniques. We have located over most of the North American Continent a device called a riometer which is simply a device which gathers radio waves from stellar space and determines the amount of absorption caused by the aurora. This is part of the radio program of the auroral studies. This is in addition to the network of radars which study radio reflections from aurora.

I think perhaps this is enough on the background, and in order not to hold up things I will go ahead with some of the accomplishments.

ANTARCTIC AURORA

For the first time the IGY has produced, and this is a United States program, valuable spectra at the South Pole of the aurora made in the South Pole regions.

In the past, up until the IGY, there were no spectra that were usable in any sense of the word. The only spectra which were available were some which were made by a French expedition when I was in Paris a couple of years ago; actually before that. I examined these spectra and they were useless; they were made with instrumentation which was outdated. It is only during the past year, since the early fifties, that any great steps have been made in optical instrumentation to study the aurora, and these were made here in this country.

We sent spectrographs to the Antarctic of several kinds, and they are at all of our stations, as a matter of fact at 6 stations, 5 of our own and a cooperative station at New Zealand. These spectrographs took spectrum after spectrum after spectrum during the period of the dark season in the Antarctic. These data have just returned; the last shipment came in about a week or so ago, and there is great excitement over examining the spectra.

In addition to this we have spectrographs in cooperation with the New Zealanders at South Island and in New Zealand, where there is the same type of spectrograph as in the Antarctic. We have some high dispersion instruments at New Zealand in addition which give us an opportunity to examine the spectrum in great detail.

One thing which never has been settled is whether the spectrum of aurora australis, the southern aurora, is the same as aurora borealis. The question has not been answered. Most of us suspect it is the same but we have to verify this.

The other question is this: From a physical point of view it is necessary for us to know whether or not auroras occur simultaneously in both hemispheres. The evidence is that it does. Some radar studies indicate that it does, but this again is a little preliminary because the data is delayed by the fact that it cannot come back in a reasonable length of time and has to wait for shipboard transportation. We are afraid to risk our original data aboard aircraft so we ordered it back by ship.

VISUAL OBSERVATIONS

The visual program is an extremely extensive program. I hesitate to say how many visual volunteer observers there are cooperating, but it is a tremendous number. In the United States we have over 700 volunteer observers alone who go out every night and look for aurora. They are supplied with special punchcards which facilitate the production of data, and they send them to our collection center in Ithaca, N. Y.

This program would accumulate tons of data if it were not for the fact we are using punchcard methods which enable us to get this data into machines and in a useful form very quickly.

Taking a page from the meteorologists book again, because of the fact we have such a tremendous synoptic network, we are plotting synoptic maps of the occurrence of aurora and their motions. These maps are plotted on an hourly basis for every night of the year during IGY, and on a 15-minute basis during special intervals.

ALL-SKY CAMERA DATA

To supplement this we have an all-sky camera program which again is part of a rather large extensive network, one being a longitude net-

work and the other a latitude network. These take pictures every few minutes of the aurora and enable us to get coverage where you do not necessarily have visual observers.

Mr. YATES. Are these synchronized?

Mr. OLIVER. Not necessarily, but they are timed within a minute or two all over. In other words, we attempt to get a picture, say, at zero minutes of each hour, and this is correct to within a minute or two. This is not critical so far as the aurora itself is concerned.

This camera chain again goes all the way from Thule down through Canada (Canada has cameras quite similar), down into the United States, and I guess our last camera is perhaps down in New Mexico. The cameras were also in the Antarctic along with the spectographs at each station.

Just to go back to the visual program for a minute, this is another program which was very carefully integrated with the worldwide program. The New Zealand observations are compatible with ours, and the Australian, the Norwegian, and the Canadian observations are almost identical, so that the data on an international basis is compatible.

THE GREAT AURORA

I was going to elaborate a little bit on the aurora of February 10, 1958, but I think enough has been said on this without going into any further detail. The interesting part about the February 10 aurora was the fact that within a few hours we had over 2,000 observations in the United States alone.

Mr. THOMAS. Two thousand?

Mr. OLIVER. Within a few minutes.

HEIGHTS OF AURORA

Mr. THOMAS. What good information did we get out of that which we did not heretofore have? Give us a little in the way of the practical aspects of that investigation.

Mr. OLIVER. We never had been certain about the heights. In order to measure heights of aurora one has to have 1 of 2 things. Either one needs many visual observations made with some sort of an instrument, an inclinometer or some sort of instrument so you can get observations from several points. Then, knowing the distance between the points, one can estimate the distance by simple trigonometry. Or one needs a pair or more of cameras taking simultaneous photographs which is a little difficult. It has been done, but it is difficult.

By having so many observations, and so many possible points between which one can compute, you can get accurate estimates of these heights.

I think it is important that most of this information did reveal the fact that these red aurora did not go below 120 kilometers.

Mr. YATES. One hundred and twenty kilometers from where?

Mr. OLIVER. The surface of the earth. In other words, this is 120——

Mr. THOMAS. What is the distance of a kilometer?

Mr. OLIVER. One hundred kilometers is sixty miles, a factor of 0.6. Multiply miles by 1.6 to get kilometers.

Probably at no time in past history were more spectrographs trained on any event as on this red aurora. Spectrographs of all kinds were trained on it. Radar instruments of all kinds were trained on it. It was the most carefully and thoroughly observed aurora in history. We had adequate warning through the warning center that this might occur and everybody was ready and waiting and we were not unhappy about the event.

POLAR TWILIGHT OBSERVATIONS

In the Antarctic again we had two other rather interesting experiments which were planned in advance of the IGY. One of them was the observation of the twilight at the South Pole. The South Pole provides a most unique platform on the face of the earth for these things. We do not have a fixed ground platform at the North Pole, but at the South Pole we have, so that we can look at the sun, or look at the atmosphere, the same part of the atmosphere illuminated by the sun as the earth rotates.

This was fortunate from our point of view as well as from Mr. Shapley's that we could examine precisely the same spot on the atmosphere. We can make twilight studies at lower latitudes but only for short periods of time, for a few hours, perhaps, or a few minutes. At our latitudes it is a matter of a few minutes. If it strikes at the 100-kilometer level it is a few minutes. Down there it is for 24 hours so we can study this thing for a long period of time.

These observations turned out very well and they are in the process of being analyzed.

ANTARCTIC METEOR OBSERVATIONS

Another program in the Antarctic which was designed as part of the auroral program simply because it was optical, I imagine, was the meteor program. The purpose of this meteor program was to determine whether or not we could verify some previously obtained evidence concerning the number of visual meteors which entered the earth's atmosphere in a certain period of time.

There had been indications that an excessive number of meteors, some factor of 10 to 60 greater than were observed at moderate latitudes, appeared in the South Pole regions. Why this would be, none of us dared guess. Some suggested that perhaps this was due to the fact that the atmosphere was exceedingly clear on certain occasions.

Well, one considers the fact that if he is to observe meteors of relatively faint magnitudes, the number of clear nights would have to be extremely small, because so many things have to be left out. There can be no moonlight, there can be no aurora, there can be no blown snow or ice, and it would have to be crystal clear. In analyzing this it turned out there were only about 10 days a year in the vicinity of Little America where you could observe these.

We attempted to observe these, I have looked into this, and it does not look as if the excessive number is verified. It looks as if the same number occurred there as occurred in the moderate latitudes. We do not feel we want to make this statement in an absolute sense. We certainly will continue the observations through another season and then reexamine the whole picture.

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AIRGLOW INSTRUMENTATION

The airglow program I mentioned briefly consists of the use of photometers. Photometers for airglow are rather useless in the auroral regions because there is so much aurora we would be confusing aurora and airglow, anyway.

To get to a little lower latitude, in the southern part of Canada, for instance, we have a photometer chain which starts in Canada, goes straight down the United States, to Mexico City, Peru, and down into Chile. It is a very fine chain.

Dr. Roach again, not only from the standpoint of the observation program, but from the data reduction, has done an excellent job in setting up the machine in a very special way so that by feeding the data cards into the machine he can plot the intensity and distribution of intensity of the aurora and the night airglow very rapidly.

AURORAL INDICES

One area we are looking into very carefully is this: Since all these observations are of no use unless properly presented in a form which can be useful to the researcher, we need to have an index of auroral activity. We have essentially an index in magnetic activity—I guess several indices of magnetic activity. We have an index of solar activity. We do not have any of auroral activity, and we have none for radar auroral activity. We do not have any for airglow, and we do not have any for cosmic rays.

I think one of the important things that still remains to be done in the near future, before we get too far in publication, is to see if we can come up with an index of our auroral activity.

Another one of the principal benefits to be gained from this program as part of the IGY is the fact that simultaneously we are making auroral measurements, geomagnetic measurements, ionospheric measurements, cosmic ray intensity measurements, and solar radiation measurements all over the world. This is one thing which was lacking. Anyone who wanted to do research on the aurora had a very difficult time trying to find simultaneous observations.

I have a brief résumé of this which will be submitted for the record.

Mr. THOMAS. Thank you. That was a most interesting statement.

IGY ROCKETRY PROGRAM

Dr. KAPLAN. Now I would like to introduce Dr. Homer E. Newell, Jr., who is vice chairman of the Technical Panel on Rocketry for our Committee, and Superintendent of the Atmosphere and Astrophysics Division of the Naval Research Laboratory. In spite of his youth he is a pioneer in the use of rockets in the upper atmosphere.

Mr. THOMAS. You are welcome, Doctor. We may not turn you loose for a long time.

Dr. NEWELL. Thank you, Mr. Chairman.

You have a copy of my prepared statement.

(The statement follows:)

IGY Rocket Program

Some 200 rockets are involved in the United States IGY rocket effort. Firings are underway in the Arctic, Antarctic, Pacific, and continental areas. A major facility at Fort Churchill, Manitoba, within the north auroral zone, was constructed in cooperation with Canada, and a joint Canadian-United States program is being carried out.

The United States IGY program in rocketry actually began on July 5, 1956, at Wallops Island, Va., when the first IGY test rocket was fired successfully. There were 29 rockets fired in the pre-IGY test period. These included Aerobees, Rockoons, and Nike-Cajuns. Firings took place at the newly erected facilities at Fort Churchill as well as at White Sands, N. Mex., and Guam, and from shipboard off the California coast and in the North Atlantic. These firings were successful, and the preliminary information gained was of considerable value in the final detailed planning of the schedules for firings during the IGY period.

By May 1, 1958, some 116 rockets had been fired during the IGY. Included have been those in programs conducted at Fort Churchill (21 Aerobees, 20 Nike-Cajuns); White Sands (2 Nike-Cajuns, 1 Aerobee, 1 Nike-Asp); Point Mugu, San Nicolas Island, Calif. (14 Nike-Deacons, 1 Nike-Asp); Alamogordo, N. Mex. (2 Aerobees); a shipborne operation in the Arctic (18 Rockoons); and a shipborne operation in Pacific and Antarctic waters which were concluded in mid-November 1957 (36 Rockoons).

Fort Churchill Program

The major effort of the United States-IGY rocket program is centered at the new rocket-launching facilities, especially constructed for the IGY in cooperation with the Canadian IGY Committee and Government, at Fort Churchill, Manitoba, Canada. Some 41 rockets have been launched at Churchill during the IGY carrying a wide scope and diversity of instrumentation. The launchings to date have resulted in a remarkably successful program with 33 of the 41 launchings resulting in good rocket performance and satisfactory data. During a single 48-hour period in January 1958, in the midst of the Arctic winter, 5 rockets were successfully launched, demonstrating the utility of this new and important rocket facility.

Experimental results

Experiments are being conducted in many fields, some of which are the following:

Atmospheric structure: Pressure, temperature, density, winds
Magnetic field of the earth
Auroral particles
Cosmic ray intensity
Ionospheric charge density
Horizon studies

Participating research organizations include the following: Air Force Cambridge Research Center, University of Michigan, Naval Research Laboratory, Signal Engineering Laboratories, State University of Iowa, and the Army Ballistic Research Laboratories. Major scientific results are summarized as follows:

Ion composition of the Arctic ionosphere.—Three Aerobee-Hi rockets instrumented with radio frequency mass spectrometers were launched to peak altitudes of from 126–155 miles. The primary purposes of the experiment were to determine whether or not diffusive separation was present in the upper atmosphere and to determine the nature and number of positive and negative ions present above the same level.

Positive and negative ions were detected on all three flights. It was found that ionized nitrogen oxide was a very important constituent of the ionosphere below 120 miles and that during the daytime ionized molecular oxygen is present below 60 miles and ionized atomic oxygen is present above 90 miles. This new information on the electrical composition of the lower ionosphere is of great importance to theoretical studies of the interaction of solar radiation and atmospheric molecular constitutents.

Structure of the Arctic upper atmosphere.—Results from two Aerobee-Hi rockets launched during 1956–57 have been compared with structural information derived from rockets launched during 1953–54 from high-altitude skyhook

balloons. Tentative results have indicated that at 200 kilometers the summer daytime atmosphere density at 59° north latitude is 2.5 times the winter daytime value; and 20 times the winter nighttime value. The summer daytime value is 6.5 times the corresponding value at White Sands, N. Mex.

At lower altitudes, between 30–45 kilometers, density measurements have indicated that seasonal and latitude variations are less than 10 percent, while summer pressure measurements show Arctic temperatures and pressures to be significantly higher than values determined at lower latitudes.

United States IGY rocket results at Fort Churchill to June 1, 1958

EXPERIMENT CODE

P—Pressure
T—Temperature
D—Density
W—Winds
M—Magnetic field
AP—Auroral particles
CIC—Chemical and ion composition
HS—Horizon study
C—Cosmic ray intensity
CD—Charge density in ionosphere

PRE-IGY PERIOD

IGY rocket No.	Launching date	Experiment	Results		
			Experiment performance	Rocket performance	Peak altitude (miles)
AM 6.31	Oct. 20, 1956	PTD	Satisfactory	Normal	70.
AM 2.21	Oct. 23, 1956	PTD	do	do	90.
NN 3.02	Nov. 5, 1956	AP	Unsatisfactory	Unsatisfactory	Unsatisfactory.
SM 1.01	Nov. 12, 1956	TW	Satisfactory	Below prediction	42.
NN 3.07	Nov. 15, 1956	AP	do	do	80.
NN 3.12	Nov. 17, 1956	PD	do	Normal	130.
NN 3.17	Nov. 20, 1956	CIC	do	do	158.

DURING IGY

NN 3.08F	July 4, 1957	CD	Satisfactory	Normal	160.
NN 3.09F	do	CD	Limited data	Unsatisfactory	10.
SM 1.02	July 22, 1957	TW	Satisfactory	Normal	57.
SM 1.03	July 23, 1957	TW	do	do	54.
NN 3.13F	July 29, 1957	PTD	do	do	131.
AM 6.32	July 30, 1957	PTD	Unsatisfactory	Unsatisfactory	14.
SM 1.04	Aug. 12, 1957	T	Satisfactory	Below prediction	46.
SM 1.05	Aug. 19, 1957	TW	do	Normal	58.
RPX 6.X1	Aug. 23, 1957	Test	do	do	70.
SS 6.38	Aug. 24, 1957	TW	Unsatisfactory	Unsatisfactory	Unknown.
SM 2.06	Aug. 25, 1957	TW	Satisfactory	Normal	81.
II 6.22F	Aug. 27, 1957	AP,C	No data	Unsatisfactory	Unknown.
II 6.23F	Aug. 30, 1957	AP,C	Limited data	Normal	70.
AM 4.01	Sept. 1, 1957	PTD	Satisfactory	Satisfactory	99.
SS 6.39	Dec. 10, 1957	TW	Unsatisfactory	Unsatisfactory	Unknown.
SM 1.07	Dec. 11, 1957	TW	Satisfactory	Normal	53.
SM 1.08	Dec. 14, 1957	TW	do	do	50.
AM 6.34	do	PTD	Unsatisfactory	Unsatisfactory	Unknown.
AM 6.02	Jan. 25, 1958	PTD	Satisfactory	Normal	100.
NN 3.03F	do	AP,M	do	do	112.
SM 1.09	Jan. 27, 1958	TW	do	do	61.
SM 2.10	Jan. 27, 1958	TW	do	do	94.
AM 6.36	do	PTD	do	do	80.
AM 6.03	Jan. 29, 1958	PTD	do	do	100.
NN 3.10F	Feb. 3, 1958	CD	do	Below prediction	86.
NN 3.11F	Feb. 4, 1958	CD	do	Normal	146.
II 6.24F	Feb. 13, 1958	AP,C	do	Below prediction	80.
II 6.25F	Feb. 16, 1958	AP,C	Satisfactory	Below prediction	75.
NN 3.18F	Feb. 21, 1958	CIC	do	Normal	140.
II 6.26F	do	AP,C	do	Below prediction	80.
NN 3.14F	Feb. 24, 1958	PTD	do	do	128.
AM 6.37	do	PTD	do	Normal	89.
II 6.27F	do	AP,C	do	Below prediction	80.
RPX 6.X2	Feb. 26, 1958	Test	do	Unsatisfactory	Unknown.
AM 6.04	Mar. 4, 1958	PTD	Failed	Unknown	Do.
AM 6.05	do	PTD	Satisfactory	Normal	105.
NN 3.04F	Mar. 15, 1958	AP	do	Below prediction	78.
NN 3.05F	Mar. 22, 1958	AP	do	Normal	104.
NN 3.19F	Mar. 23, 1958	CIC	do	Below prediction	128.
OB 6.08	Mar. 24, 1958	HS	do	Normal	74.
AM 6.38	do	PTD	do	do	85.

Diffusive separation of gases in the upper atmosphere.—Diffusive separation of gases under gravity in the ionosphere is one of the major phenomena which play an important role in the modification of the composition of the upper atmosphere. An experiment carried out during the Arctic winter night has measured the composition of the upper atmosphere between 105–240 kilometers by means of a rocket-borne radiofrequency mass spectrometer. Ninety-six spectra were obtained on the ascent of the rocket and seven spectra on the descent of the rocket. From an analysis of these spectra, data have been obtained which show that there was diffusive separation of argon and nitrogen in the region 112–150 kilometers. Data obtained on the general composition of the upper atmosphere over the regions covered in flight also show the presence of atomic oxygen.

Meteorological soundings.—Some 30 upper atmosphere rocket soundings have been made in the Arctic during the IGY to measure temperature, pressure, density, and winds. Aerobee and Nike-Cajun vehicles have been utilized and experiments have included the freely falling sphere for measuring densities, the rocket-grenade experiment for the measurement of temperatures and winds, and several aerodynamic techniques for measuring pressures and densities in the supersonic flow.

It has been determined that the distribution of pressure and temperature in the atmosphere at high latitudes is very different from what it is at lower latitudes. Many of these rockets attained altitudes greater than 200 kilometers, and thus the first density measurements made at high latitudes were recorded. Launchings were made during both summer and winter, day and night. The resulting data indicate that the density of the high atmosphere is under strong solar control. There appear to be a latitude effect, a seasonal effect, and a strong diurnal effect; none of these effects appear at lower altitudes at Fort Churchill or at lower latitudes.

The temperature data derived from the rocket-grenade experiment have shown that the winter measurement is characterized by low temperatures below 50 kilometers. The summer results, by contrast, show extremely low temperatures at 30 kilometers. This grenade experiment utilizes an ingenious procedure and consists of carrying aloft explosive charges and ejecting and detonating them at regular intervals from the rocket. The positions of the explosions in space are accurately determined by a radio tracking system and/or ballistic cameras. The times of the explosions are determined and the times of arrival at the ground of the acoustic waves from each explosion are recorded. The temperatures and winds in atmospheric layers are then derived from the positions and times of the explosions and from the times and angles of the sound arrivals at the ground.

A firing at Fort Churchill indicated that the first atmospheric temperature maximum occurred at an altitude of about 60 kilometers. Normally this maximum is found below 50 kilometers at lower latitudes, indicating that, at northern latitudes, the rise is more gradual. (Temperatures decrease up to the stratosphere, rise during the next 20 to 30 km., decrease through the next 30 km., and then rise again.)

Winds measured at Fort Churchill have the characteristic summer-winter difference which has been observed in lower latitude measurements. The winds are weak and from the east in the summer, very strong and from the west in the winter.

Electron density measurements.—Four Aerobee–Hi rockets, instrumented by the Naval Research Laboratory, have been launched to study the ionosphere above Fort Churchill. The resultant data show the ionosphere to be a single layer, strong during the day and weak at night. Two of the rockets made important discoveries. These launchings took place during "polar blackouts," periods of disrupted communications at high latitudes. The rockets have shown that the "blackout" is due to a very dense and low D region of the ionosphere. It has been determined that this dense region exists at a significantly lower altitude, and with a much greater density, than is found at lower latitiudes. These data will be especially useful for effecting improved radio communications.

Horizon studies: Water vapor structure.—On March 24, 1958, the first of a planned series of 5 Nike-Cajun rockets was fired to obtain photographs of the horizon at a high-latitude geographical location. These photographs, which show the haze surrounding the earth as a bright band at the horizon, reveal water vapor structure as bright lines in the haze horizon band.

Tentative results from this flight show a single tropopause structure at Fort Churchill with little evidence of fine structure. In addition, it is evident that

the brightness profile across the haze horizon increases in contrast ratio much more rapidly as a function of altitude than brightness profiles witnessed at lower latitudes.

A special parachute recovery system was developed for these flights. This was the first firing of a recovery system in this vehicle in an Arctic region. The 85 pound nose section was recovered undamaged from an altitude of 74 miles.

Field operations at Fort Churchill

A significant reason for the outstanding success of the Fort Churchill IGY rocket sounding program has been the unique construction and operation of the range facilities under Arctic conditions. Since many of the IGY rocket research organizations are laboratories within the Department of Defense, an Interservice Support Coordinating Group was established to coordinate logistic and range facilities provided by the three services. The group consists of representatives of the Army Signal Corps, the Air Force and the Navy all under the supervision of a representative of Army Ordnance, which assumed responsibility for the establishment and operation of the range.

Within the agreement under which this group has worked, the Air Force has provided air transportation for personnel and equipment; the Navy provided a crew for handling and launching the rockets and also a telemetering service; the Army Signal Corps provided radar, frequency monitoring, communications, meteorological and photographic services, and the Army Ordnance Corps, in addition to providing the staff to coordinate the operation of the range, furnished a group to provide ballistic information on the rocket's flight. The Army Corps of Engineers was responsible for the construction of the range facilities.

The launching complex itself consists of an Aerobee tower, movable in any direction to compensate for winds, a building to house the Nike–Cajun (or Dan) launcher, preparation buildings, telemetering trailers, a blockhouse, a generating building, a helium building, and connecting tunnels.

Installed at various points throughout the military reservation at Fort Churchill are numerous instrumentation sites. Included are a 4-station DOVAP tracking system and ballistic cameras, 2 telemetering trailers, 2 ionosphere stations and a network of sound-ranging geophones. Also included and installed were 2 radars, range safety plotting boards and a command transmitter, a frequency monitoring station, a timing system, meteorological and wind ballistic balloon launching facilities and sites and a complete range communications system.

With few exceptions, the rockets fired at Fort Churchill have been equipped with radio doppler (DOVAP) tracking beacons. These beacons serve as telemeter transmitters in addition to their primary function in the tracking system. Excellent trajectory data have been obtained on all rockets either to peak altitude or breakup on reentry. This tracking system is in use at most of the major firing ranges in the United States and in other countries, and the operational record at Fort Churchill is unequaled. Precision of the data is such that errors in altitude of less than 100 feet at rocket peak and in velocities of less than 1 foot per second have been commonplace. Such accuracies were required in many of the scientific experiments.

Ground-based optical instrumentation has been operated at Fort Churchill to furnish positional data for certain experimental events accurate to ± 15 feet, The photographic results have also revealed certain turbulence properties of the atmosphere through observation of smoke trails at very high altitudes. Such photographic observations require a survey of instrumentation sites such that their relative positions are known with an accuracy of ± 6 inches. This was truly a major accomplishment in the Arctic terrain and under Arctic environmental conditions.

An extremely important feature of the Fort Churchill IGY rocket program has been the very close cooperation of Canadian personnel. The Canadian IGY Committee and Government have provided most valuable assistance in the establishment and operation of this rocket range.

ROCKOON FIRINGS IN THE ARCTIC

During the period August 5–14, 1957, 18 rockoon (balloon-launched rocket) flights were conducted as part of the United States-IGY program by a team of scientists from the State University of Iowa. The firings were made from the U. S. S. *Plymouth Rock* in the sea area bounded by Greenland, Labrador, Baffin Island, and Devon Island between latitudes 55° N. and 76° N. These firings,

which resulted in the first high-altitude magnetic measurements made within the northern auroral zone, also constituted an excellent survey for the first time of auroral particles and their association with actual aurorae.

Preliminary results

Good scientific data were obtained up to 22 kilometers during the balloon phase of 13 of the 18 flights; on 7 of these, good data were obtained throughout the rocket flights as well. Peak rocket altitudes ranged from 77 kilometers to 132 kilometers. A brief report of the results follows:

(*a*) The total intensity of cosmic rays through and above the atmosphere at northern latitudes is now (during the present period of maximum sunspot activity) approximately two-thirds of its value during the 1953–55 period. This intensity is nearly independent of latitude through geomagnetic latitudes ranging from 66° N. to 86° N.

(*b*) Five new sets of data on the physical nature, energy, intensity, and latitude distribution of auroral "soft radiation" were obtained. Its hardness was measured by a variety of absorbers. Preliminary indications confirm previous interpretations of this X-radiation. One of these flights is of special interest as it was a night flight to an altitude of 97 kilometers beneath a brilliant aurora that first became visible about 10 minutes before the rocket fired. Intense soft radiation was observed by the rocket-borne equipment. A preceding daytime flight (only 3 hours earlier) showed little or no auroral radiation up to 81 kilometers.

(*c*) A new magnetic electron spectrometer with a crystal detector was flown for the first time, reaching a maximum altitude of 87 kilometers.

(*d*) A miniature proton precession magnetometer was test-flown successfully. The purpose of the experiment was for the precise measurement of the absolute scalar magnitude of the total terrestrial magnetic field in the auroral zone. On a flight to 118 kilometers on August 6, 1957, excellent magnetic intensity data were obtained at 2-second intervals. The data show a large discontinuity in precessional frequency at an altitude of about 90 kilometers on the down leg of the trajectory. However, it appears that the rocket spin correction, not yet applied, will account for this discontinuity.

(*e*) Correlation is being made of fluctuations of upper atmosphere cosmic-ray intensity with (i) solar and magnetic data from ground stations, (ii) cosmic-ray data from balloon flights at Fort Churchill, Manitoba, and Minneapolis, Minn., and (iii) neutron monitor data at various ground stations.

ROCKOON FLIGHTS IN THE ATLANTIC, PACIFIC, AND ANTARCTIC AREAS

From September 26 to November 9, 1957, 36 rockoons were launched from the Navy icebreaker, U. S. S. *Glacier*, as part of the United States-IGY program. The first rockoon launching in this series was at 30° N. in the Atlantic and the last was at 72° S. in the Ross Sea adjacent to Antarctica.

This work, together with earlier launchings in the Arctic in August 1957, constitutes a unified high-altitude investgation of cosmic-ray, auroral and geomagnetic phenomena from 75° N. to 72° S. latitude by the State University of Iowa.

The *Glacier* sailed from Boston on September 23, 1957, and proceeded to the Line Islands area in the central Pacific, then sailed south, entering the Antarctic ice pack on October 31 at about 66° S., 178° W., and penetrating the pack to 72°05′ S., 176°30′ E.

Launchings were concentrated in the region of the Line Islands in the central Pacific, within the southern auroral zone in the South Pacific, and the Ross Sea. In addition, a series of flights was conducted along the ship's track, and two flights were made off the coast of New Zealand in a cooperative study with the low-frequency ionospheric station of Canterbury University College.

Flight summary

As in the earlier work in the Arctic, the Hawk rockoon vehicle was used. The rocket was a modified Loki II solid-propellent unit with the experimental apparatus fitted to the forward end in a pointed cylinder. The payload (the weight of the instrument package) varied from 8 to 9.5 pounds. The rocket was suspended on a long lead line beneath a 26,000-cubic-foot plastic balloon. It was fired by a barometric pressure switch when the balloon reached an approximate altitude of 23 kilometers. The rockets reached altitudes of about 125 kilometers.

All balloons performed satisfactorily, although two were damaged during inflation and were discarded. Of the 36 rocket-launching attempts, 20 can be considered normal flights, with summit altitudes ranging from 105–135 kilometers. Seven rockets did not fire; 2 performed erratically; 6 were lost owing to equipment failure; and 1 was lost at launching, in a squall.

Objectives and results

A major purpose of the rockoon program is measurement of total cosmic ray intensity over a wide range of geographic and geomagnetic latitudes during the present period of high solar activity. Special points of interest are (i) comparison of the intensity at upper atmosphere levels in high southern latitudes with intensity at high northern latitudes, and (ii) investigation of the location of the latitude "knee" (the geomagnetic latitude at which the number of incoming particles appears to fall off sharply) in the southern hemisphere.

Satisfactory cosmic ray intensity measurements up to an altitude of 23 kilometers were obtained in a total of 15 flights distributed along the ship's track from 25° N. to 72° S. On four flights satisfactory intensity data at upper atmosphere levels were obtained. These flights were made in many latitudes, but a variety of equipment failures caused a gap in the measurements in the vicinity of 30° S.

Flight data which have been read and reduced to date indicate that the total cosmic ray intensity at upper atmosphere levels in high southern latitudes is within 5 percent of that in high northern latitudes, and about 4.3 times as great as that near the equator. They also show that during the present period of high solar activity the latitude knee is found at a latitude lower than 50° S. Cosmic ray intensity at various altitudes is being systematically plotted against geomagnetic latitude.

Another aim of the program was precise measurement of the intensity of the terrestrial magnetic field to altitudes over 120 kilometers in the region of the equatorial electrojet. For these studies, a miniaturized proton precession magnetometer was used. A detailed comparison of these data with simultaneous measurements made independently with variometers at the nearby IGY magnetic observatories on Palmyra, Fanning, and Jarvis Islands, in the Line Islands group, is being made. Special interest was attached to the detection and measurement of electrical currents in the ionosphere by means of devices extending outward from the sides of the rocket. Such devices permit direct contact with the surrounding atmosphere.

Four satisfactory sets of data on magnetic intensity were obtained in the Line Islands area at altitudes up to 135 kilometers and flight data reduced to date indicate new evidence for the existence of electrical currents in the lower ionosphere. On a fifth flight the magnetometer operated properly but the rocket's peak altitude was less than 70 kilometers. The full reduction of all four sets of flight data obtained in the Line Islands area, when combined with the ground station measurements, are expected to yield illuminating information on the equatorial electrojet.

Precise absolute measurements of the intensity of the terrestrial magnetic field at sea level were taken at a number of new locations. Two new series of absolute values were obtained. The first series, in the Line Island area, showed the current magnetic chart of the United States Hydrographic Office to be correct within the limits of accuracy indicated. The second series of measurements, made in the Ross Sea showed another chart, which was based on limited data, to be substantially in error in that region. The new values will be published shortly.

Several other experiments were conducted in the southern auroral zone. High-altitude measurements of the magnetic field were made for correlation with nearby Antarctic observations. There were three successful magnetometer flights. Investigations were made here of the physical nature, intensity, and latitude distribution of the "soft radiation" associated with auroras. A flight at 70°48′S, 175°50′E was the only successful rocket flight of auroral instrumentation made in the zone. It encountered a high intensity of soft radiation resembling that studied extensively in the northern auroral zone during Iowa rockoon expeditions from 1953 to 1957.

ROCKET FLARE PATROL PROGRAM

Valuable data on solar X-rays during solar flares were obtained during July and August 1957 from 14 rocket launchings from San Nicolas Island, within the United States Navy Point Mugu Range, 60 miles off the California coast. These

launchings which reached altitudes of up to 80 miles, were part of the DAN Rocket flare patrol program, which is designed to determine the radiation source of the radio fadeouts caused by flares on the disk of the sun.

This IGY rocket program was conducted by the Naval Research Laboratory and was primarily directed toward determining the radiation source of the fadeouts resulting from flares observed on the disk of the sun. For the first time, measurements were made of X-ray and ultraviolet bursts from the sun during a solar flare. These data will help in explaining radio blackouts, which are present during periods of unusually high degree of ionization, and which are closely associated with solar flares.

Scientific results

The scientific results of the program to date are of considerable interest. New geophysical data on solar X-rays have been obtained for flares of class 1+, 2 and 3+ magnitudes, as well as background data under no-flare conditions. From preliminary inspection of the telemetered data certain features of the X-ray emission are quite clear. A flare produces a marked increase in X radiation of short wavelength, or hardening of the X-ray spectrum, compared to that of the quiet corona. The largest flare produced the shortest wavelength X-ray emission. The total X-ray flux was less for the class 1+ flare than for the class 2 flare. An estimate has not yet been made of the flux in the class 3+ flare but it appears that hardness of the spectrum may play a more important role than total flux in accounting for the associated sudden ionospheric disturbances.

In every case, an attempt was made to time the rocket firing with the expected maximum phase of the flare. In each firing, therefore, the first few minutes of flare development were bypassed. No evidence has been obtained for large increases in Lyman alpha during any of the flare firings. However, this does not justify ruling out the possibility of a Lyman alpha flash very early in a flare.

Field operations

In the course of the program, several advances in the techniques of using small rockets for research purposes have been accomplished. A new type of aerodynamic telemetering antenna, with uniform radiation pattern, was developed and gave perfect telemetering performance on all flights. Extensive data on the yaw behavior of small rockets above the restraining influence of atmospheric stabilization have been obtained. The effect of using no second stage closure (NACA system) on ignition delay and subsequent rocket yaw has been observed and photographed, and a closure system for the two-stage trajectory configuration has been developed. The practicability of command firing of small rockets with only a 60-second delay has been proven. The practicability of rapid repeated firing of small research rockets from a single rocket launcher has been confirmed. Measurements of skin temperature were made. Data were accumulated on the effect of rocket yaw on altitude. Boosters have been visually tracked and some experimental information on the influence of wind on the rocket's trajectory is available. Much detail on rocket behavior is contained in the telemetering records yet to be analyzed.

Dr. NEWELL. I would like to add to that a few remarks on some of the more interesting aspects of the rocketry program.

By the rocketry program we mean the use of vertical sounding rockets in contradistinction to satellites. The vertical sounding rocket is launched from the surface of the earth in as nearly a vertical trajectory as one can get, and then returns to the earth in a matter of minutes. The total flight of the vertical sounding rockets varies from, say, 5 minutes to 10 minutes. During that period one has to make the observations that one wants.

AEROBEE ROCKET

In the case of the United States-IGY program we are using three classes of vertical sounding rockets: One is the larger Aerobee, of which we have something like four different versions, three of them called the Aerobee and the fourth the Aerobee-Hi. The Aerobee rocket is 15 inches in diameter and varies from 19 feet in length to

about 24 feet. The largest version, the 24-foot version, the Aerobee-Hi, can carry 150 pounds of equipment up to 160 or 170 miles. If we reduce the payload to 120 pounds we can get equipment up to 190 miles.

NIKE-DEACON AND NIKE-CAJUN

The second class of rocket is a two-stage solid propellent vehicle, a combination of the Nike booster, which is the booster for the Nike antiaircraft missiles, and a small rocket such as the Deacon or Cajun. The Deacon and Cajun rockets are 6 to 8 inches in diameter, depending on how you build the airframe around it, and about 9 feet long.

I have given you here the dimensions of the bottle, just the motor that you get from the manufacturer. The upper air researcher then adds to it fins to stabilize it and a nose cone carries his instrumentation. With the Nike-Deacon or the Nike-Cajun combination one can send 50 pounds of equipment up to about 60 miles.

ROCKOONS

Then the third class of vehicles we are using during IGY is the so-called Rockoon. This is a term compounded of "rocket" and "balloon." This is the technique which was pioneered by Dr. Van Allen a number of years ago. In the Rockoon one uses a large balloon like the Skyhook and hangs a small rocket like the Deacon or the Cajun or the Hawk vehicle. The Hawk belongs to the class of rockets which were used as second, third, and fourth stages in the Jupiter-C, which launched our first satellite. The Hawk, however, is a smaller vehicle than the rockets which were used in that satellite vehicle. These small rockets are then launched in the stratosphere after the balloon has reached its peak altitude.

To give you an example of what one gains by this technique, if one were to launch the Deacon from the ground—just fire it on the ground—it would go up to about 20 kilometers. On the other hand, if one launches it from 20 kilometers, which is the peak altitude, say, of the skyhook balloon, then it goes up to 100 kilometers. This gain in performance is due to the fact that one has lifted the rocket above the denser lower atmosphere. One then avoids the drag that the lower atmosphere imposes on the vehicle.

For the same reason we use the Nike booster in the Nike-Cajun and Nike-Deacon combinations which I mentioned earlier. Again, the Nike booster lifts the Deacon or the Cajun up into the stratosphere before it is fired, and again one avoids the drag on the vehicle.

These, then, are the vehicles that we have been using during IGY for our program. The total effort comprises the firing of about 200 of these sounding rockets.

It is interesting to note that this effort during IGY, during the 18 months of IGY, is about equal to the total effort from 1946 up to the beginning of IGY in numbers of rockets. So in going into the IGY program we were perhaps a little presumptuous to think that the same team which carried out——

Mr. THOMAS. Are these missiles guided, Doctor?

Dr. NEWELL. These are not guided missiles. These are sounding rockets with a small amount of control necessary to keep them on the

firing range, but they are not guided in the sense of a missile which has in it equipment to pinpoint the impact point.

Mr. YATES. Do you recover the equipment?

Dr. NEWELL. In some cases; yes. In some cases the equipment is recovered simply by destroying the rocket by severing it at some appropriate point near the base of the instrument container. Then the aerodynamic streamlining is spoiled and the two parts drift down. They pancake into the earth.

For example, in the case of the V–2 rocket which we used in the early days of our program, if the rocket had not been destroyed it hit the earth at more than 5,000 feet per second and just dug a tremendous crater. In one case the V–2 rocket, which consists of tons of deadweight, hit the earth without being destroyed previously and dug a crater 80 feet across. After sifting through the sand in that crater for 2 weeks, we got 3 bushels of little pieces of material. That is all.

On the other hand, when we sever the rocket, then it hits the earth at about 200 feet per second, and this is such that we can recover appropriately protected equipment from it. In fact, from such flights where the rocket was severed in air, we have recovered delicate instruments like spectrographs and reflown them a number of times before the instruments finally wore out.

EXTENT OF PROGRAM

As I was pointing out, in the IGY effort we have something like 200 rockets which in the sense of numbers of rockets doubles the program that this country has been carrying on since 1946. This doubling takes place in a year and a half as compared to the first 10 years of this sort of work. However, in the sense that we had the first 10 years of experience behind us, the IGY effort does more than double the effort. We know what we want to measure. We know how to measure it. We know how to fly the rockets.

During the first 10 years of our rocket-sounding experience we had a sort of rule of thumb that two-thirds of our experiments would work and one-third would not. This was the cost of doing upper air research. During the IGY effort, however, we find that something like 90 percent of all these rocket firings have worked.

IGY ROCKETRY OBJECTIVES

Mr. THOMAS. Will you permit a slight interruption here. If we are annoying you, you tell us.

Dr. NEWELL. Not at all.

Mr. THOMAS. What are you looking for, and what do you hope to gain after you find what you are looking for?

Dr. NEWELL. I have a list of those things I will come to in a moment, if you will permit me.

Mr. THOMAS. Go right ahead.

Dr. NEWELL. In the case of the rocket-sounding program, I would like to point out we have not a scientific discipline, as was the case when Dr. Simpson discussed cosmic rays or when Norman Oliver discussed the aurora, airglow, and so on. Rather, we have the application of a technique to a variety of disciplines.

KINDS OF ROCKET EXPERIMENTS

In using the rocket we attempt to measure things which can be measured only with rockets. We cover atmospheric structure. This is pressure, temperature, density, winds. All these are studied in other disciplines, such as in meteorology, for example, except that we are trying to make these measurements up where balloons will not go. We are trying to make them where no one else can make them. We are studying the magnetic field of the earth, a program which was described by Dr. Simpson in connection with cosmic rays.

The magnetic field measurements that we are trying to make, however, are made up in the ionosphere, where magnetometers cannot get unless rockets carry them.

We are trying to measure auroral particles, the particles which Mr. Oliver described earlier, which give rise to the northern and southern lights.

We are trying to measure cosmic ray intensity in the upper atmosphere and the charged density of the ionosphere. We are trying to study the earth from above.

Mr. THOMAS. You are trying to cover the waterfront.

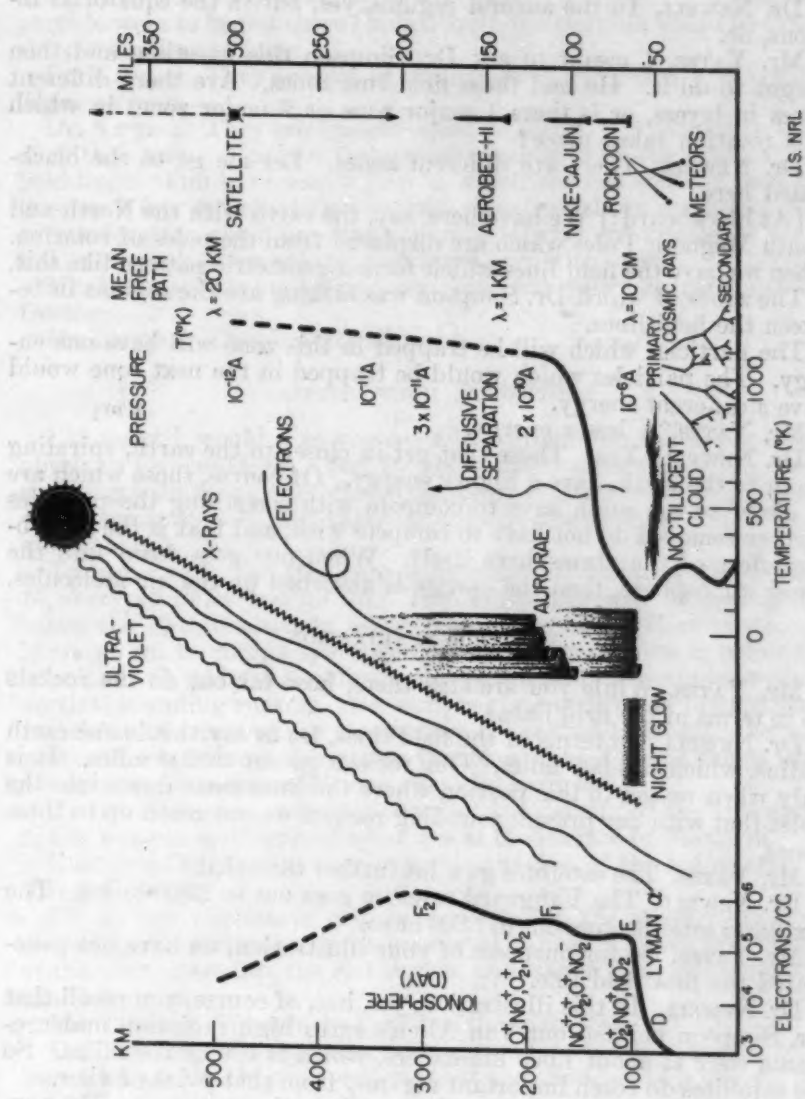
Dr. NEWELL. In covering this waterfront, however, we are attempting to use the rocket in the way in which it has unique application, that is, to make measurements which nobody else can make.

For example, we study the sun from the upper atmosphere, but we study the sun to determine what radiations the sun emits which do not get to the surface of the earth. Various radiations are absorbed in the upper atmosphere in the ultraviolet wavelengths and the X-ray wavelengths. Therefore, the observer on the ground cannot see these. We have to send equipment into the upper atmosphere to study these radiations; also to determine where they are observed; also to determine what reactions they cause.

I thought before I plunged into a discussion of what we have learned in these various areas I would give you a little background on the upper atmosphere to give you a feel for the difference between the upper regions of our atmosphere and the lower region in which we live.

This is the only copy I have of this chart, which I shall be happy to leave.

(The chart referred to follows:)


MILES
350
300
250
200
150
100
50
SATELLITE
AEROBEE-HI
NIKE-CAJUN
ROCKOON
METEORS
MEAN FREE PATH
PRESSURE
T(°K)
λ = 20 KM
λ = 1 KM
λ = 10 CM
10⁻¹²A
10⁻¹¹A
3x10⁻¹¹A
2x10⁻⁹A
10⁻⁶A
DIFFUSIVE SEPARATION
PRIMARY COSMIC RAYS
SECONDARY
ELECTRONS
X-RAYS
ULTRA-VIOLET
AURORAE
NOCTILUCENT CLOUD
NIGHT GLOW
IONOSPHERE (DAY)
F2
F1
E
D
LYMAN α
O⁺,NO⁺,O₂⁺,NO₂⁻
NO⁺,O₂⁺,O⁻,NO₂⁻
O₂⁻,NO⁺,NO₂⁻
KM
500
400
300
200
100
10³ 10⁴ 10⁵ 10⁶
ELECTRONS/CC
0
500
1000
TEMPERATURE (°K)
U.S. NRL

ROCKET PENETRATION OF MAGNET ZONES

Mr. YATES. Do your rockets go as high as the buffer zone which Dr. Simpson talked about, the area where the sun particles are rotating from pole to pole?

Dr. NEWELL. In the auroral regions, yes, but in the equatorial regions, no.

Mr. YATES. I meant to ask Dr. Simpson this question, and then forgot to do it. He had these field line zones. Are there different zones in layers, or is there 1 major zone or 2 major zones in which this rotation takes place?

Dr. NEWELL. There are different zones. Let me go to the blackboard here.

[At blackboard:] We have here, say, the earth with the North and South Magnetic Poles which are displaced from the poles of rotation. Then we have the field lines which form a geometric pattern like this.

The zones of which Dr. Simpson was talking are the regions in between the field lines.

The particles which will be trapped in this zone will have one energy. The particles which would be trapped in the next zone would have a different energy.

Mr. YATES. A lesser energy.

Dr. NEWELL. Yes. Those that get in closer to the earth, spiraling closer to the earth, have a higher energy. Of course, those which are in closer to the earth have to compete with something the particles farther removed do not have to compete with, and that is the absorbing effect of the atmosphere itself. When one gets down into the lower atmosphere, then the energy is absorbed by the air molecules.

ALTITUDE PENETRATION

Mr. YATES. While you are still there, how far out do the rockets go in terms of the field lines?

Dr. NEWELL. In terms of the field lines, let us say this is one earth radius, which is 4,000 miles. Our rockets go out to 200 miles. It is only when we get to this portion where the lines come down into the poles that with our present sounding rockets we can reach up to these zones.

Mr. YATES. The satellites go a lot further than that?

Dr. NEWELL. The Vanguard satellite goes out to 2,500 miles. The Explorer satellite goes out to 1,800 or so.

Mr. YATES. So for purposes of your illustration, we have not penetrated the first field line.

Dr. NEWELL. In this illustration, yes, but, of course, you recall that Dr. Simpson pointed out Van Allen's extra high radiation measurements were at about 1,000 kilometers, which is 600 or 650 miles. So the satellites do reach important regions, from that point of view.

Dr. WATERMAN. There are really no discontinuous zones. The particles find their own location.

Dr. NEWELL. Yes.

Dr. WATERMAN. The lines are just to indicate the direction of the field.

Dr. NEWELL. The lines are really something on which to hang your thinking. Actually, of course, the field is continuous as you go out,

unless there happens to be some current flow here which causes discontinuity in the field.

Mr. YATES They are sort of like the picture of the spectrum we see, with the colors fading into each other.

Dr. NEWELL. Except there is more reality to that than to the field lines. The field lines are the lines of magnetic force. If a magnetic particle were to be put there [indicating], the particle would be drawn along these lines of force.

Dr. KAPLAN. They are sort of contour lines, compared with contour lines on a map.

Dr. NEWELL. They are lines of equal intensity, if you want to think of it that way. You can make a comparison with the gravitational field lines. You have seen a map in which one has contour lines like this, each one representing a certain elevation above sea level. At a given elevation about sea level, there is a given gravitational potential, so to speak. One can compare these lines with these.

Mr. THOMAS. Do not let us divert you from your general statement, Doctor.

Dr. NEWELL. That is quite all right.

RAREFIED HIGH ATMOSPHERE

I thought I would give you some background on the upper atmosphere, so you could get a feel for the difference between what we are studying with rockets and the region being studied in the meteorological program by means of balloons and other methods of sounding the atmosphere.

To begin with, the atmosphere decreases in density by a factor of 10 every 10 miles you go up. This is another way of saying that, below the 10-mile altitude, 90 percent of our atmosphere exists. So, if we go up to 20 miles, 99 percent of the atmosphere is below that 20-mile level. Above 20 miles, roughly, we make our studies with the vertical sounding rockets. So, our program is directed toward learning about 1 percent of our atmosphere. Yet that 1 percent is very important to us because it contains the ionosphere, for one thing, which we use in radio communications around the world.

At 100 kilometers, which is 60 miles, the density of the atmosphere is just one one-millionth of what it is at the surface of the earth. Yet it is at 60 miles that the first important region of the ionosphere, the E region, begins.

Up at 200 kilometers, which is 120 miles, the atmosphere is one ten-millionth as dense as it is at sea level. That is where the F region of the ionosphere lies, the F–1 region, and, above it, at 300 kilometers, the F–2 region.

Mr. THOMAS. What is the height of the sputniks?

Dr. NEWELL. The sputniks came down into the F–1 region of the ionosphere. So, they dipped into that and then went up beyond that.

QUANTITY OF ATMOSPHERE

We can present this in, perhaps, an even more dramatic fashion by imagining the atmosphere to be reduced to sea-level conditions. As I pointed out, the atmosphere attenuates as we go up, becoming thinner and thinner, but suppose that, somehow or other, we could reduce

it to sea-level conditions of temperature, pressure, and density. Then we would have only 5 miles' worth of atmosphere. Although our atmosphere actually extends out to hundreds of miles, if it were reduced to sea-level conditions it would be only 5 miles' worth.

The region above 200 kilometers, in which we have a major interest, if it were reduced to 5 miles, reduced to sea-level conditions, would be only one one-thousandth of an inch out of that 5 miles' worth. This is the portion in which we have so much interest in our IGY rocket-sounding and satellite-observation program.

Mr. THOMAS. What are you looking for when you get up there, Doctor? You said a while ago you knew what you were looking for.

Dr. NEWELL. Yes; we know many of the things we are looking for.

IONOSPHERIC EXPERIMENTS

First of all, we want to find out about the ionosphere; what charge densities exist up there; how much electricity there is, in free state, up there. The ionosphere consists, roughly, of three main regions; the D region, the E region, and the F region. The D region, normally, is a rather weak region and exists at about 80 kilometers. We know this normal D region of the ionosphere is formed from hydrogen radiation from the sun; that is, Lyman alpha ultraviolet radiation emitted by hydrogen in the sun.

The E region of the ionosphere lies at about 100 kilometers, and ranges between 100 kilometers and, say, 140 kilometers. We know that this is formed mainly by X-radiation from the sun and ultraviolet light, different from the ultraviolet light which forms the D region.

The F region is, normally, divided into two, the F–1 and F–2, layers, so called. This region of the ionosphere is believed to be formed by ultraviolet radiation from the sun.

Here is one of the main problems of the IGY. We want to find out whether this is true or not, and what the wave-lengths which form this F region really are. We want to pin down, too, the altitude at which the maximum charged density of the ionosphere lies.

ARCTIC ROCKET PROGRAM

In particular we want to find out what the ionosphere is like in the auroral regions. During the first 10 years of this country's rocket sounding program, our observations were made at White Sands in New Mexico. We wanted to move from there to some significantly different region. We had a choice of going either to the Equator and studying the ionosphere there, or to the auroral region. We decided that it would be best during the IGY to attack the auroral region, and therefore we set up in the Fort Churchill area, at Fort Churchill in Manitoba, Canada, a new rocket range. This new rocket range has been set up under the direction of the Army Ordnance Department, and with the cooperation of the Army, the Navy, the Air Force, several universities—the University of Iowa and the University of Michigan—industry, Aerojet General Corp. for one, and Canada, and is being operated with the cooperation of these three.

In fact, in setting up this range and building the launching towers for our rockets, we even arranged that an Aerobee launching tower

could take the United Kingdom's special sounding rocket, so we can fire not only our own rockets but the United Kingdom can fire their sounding rockets.

The range has been extremely useful, and its usefulness after IGY should be even greater. The people who have been carrying out the upper air soundings during IGY are now looking forward to further tests in the Arctic. The Canadian Government is interested in maintaining the range and will undoubtedly carry out experiments of its own.

ARCTIC IONOSPHERIC RESULTS

In the case of the ionospheric studies during IGY at Fort Churchill, we have found that during a polar blackout when radio communications were impossible and, in fact, telephone communications were cut out so we could not communicate with the rest of Canada, the ionosphere showed a very dense D region, which I indicated normally is at about 80 kilometers. This D region extended down to below 80 kilometers. When there was not a polar blackout this D region was not particularly dense. It was what we normally found at White Sands.

ION DENSITIES

Mr. YATES. Dense in terms of what?

Dr. NEWELL. In terms of free charges. There were many more free charges than one normally found.

We found that the ionosphere during the daytime and not during a polar blackout was very much as we had found at White Sands, that it was a fairly continuous region all the way up to as far as our rockets went. We found that the ionosphere at nightime was rather thin, not nearly so dense as the normal ionosphere. But there still was an ionosphere there.

TRUE HEIGHTS

This, then, is of considerable use to us, we feel, because knowing the actual altitudes at which various charge densities exist, one can then compare the ground-based observations which Dr. Shapley described yesterday and work out a method for computing true heights.

For example, from ionosondes, one attempts to estimate what the usable radio frequencies for communications will be, and then make a prediction of what the maximum useful frequency, for example, will be. This is of value to anyone who is to set up a schedule for important communications.

In the past, the predictions have run into difficulties at times of disturbed conditions, high activity, and so on.

On the basis of the data obtained prior to IGY, researchers at Slough, England, have devised a technique for reducing their ground-based observations so as to give them true heights. The predictions that they now make are within 3 percent of being correct every time. This was not true prior to that.

This should, then, be of great practical value. The data we have now collected in the Arctic will enable researchers like those at Slough to continue this for Arctic regions as they have done it now for temperate latitudes.

Dr. KAPLAN. If I may interrupt, the characteristics of the rocket as a tool is that it makes these more easily obtained observations obtained from the ground far more valuable. This is really among its basic uses.

ARCTIC DENSITIES

Dr. NEWELL. Another parameter in which we are interested is the density of the upper atmosphere. In fact, there are three parameters in which we are interested: pressure, temperature, and density.

The pressure and density are just what you normally think of at the surface of the earth; the pressure, the weight with which the atmosphere pushes on a unit of area. The density is the number of particles per cubic centimeter or the mass per cubic centimeter, whichever way you want to think of it. The temperature in the upper atmosphere is somewhat different. It is questionable whether it has a real meaning. It is not the temperature to which a thermometer would come if you were to put a thermometer up there, the reason being that there is so little atmosphere there. There is just not enough of the air molecules to convey the heat to the thermometer to produce the equilibrium that you need when you read your temperature. In fact, the temperature of the thermometer would be determined by the radiation it gets from the sun and from the earth more than by the temperature of the surrounding medium.

So, in making measurements of these three parameters, we measure pressure and density, and then calculate temperature. This is our procedure.

In our studies at White Sands during the past 10 years, we had derived pressure and density curves which were fairly consistent, which looked as though they were probably correct. We had found that there were no diurnal effects, that the density and pressure curves remained essentially the same between day and night; and that there were no seasonal effects, that these curves remained essentially the same throughout the year.

When we went into the Arctic during the IGY program, however, we found that this was not so; that, for example, at 200 kilometers altitude at 59° north, the Fort Churchill latitude, the daytime density is 2½ times the winter daytime value. So there is a seasonal effect up there. We found that the daytime density was 20 times the winter nighttime value. So there is a marked diurnal effect which we did not find in the temperate latitude. We found that the summer daytime value is 6½ times the corresponding value at White Sands, N. Mex. So there is a geographic effect.

All of these are essential data to use in working out the dynamics of the upper atmosphere, the weather, if you want to call it that, of the upper atmosphere, and in developing a theory of the ionosphere.

We found at the lower altitudes, between 30 and 45 kilometers, just above the troposphere in which Wexler carries out his observations, that there were very little variations. So these big variations apparently occur up in the ionospheric regions.

HIGH ARCTIC WINDS

We made measurements of winds in the Arctic regions. They have an ingenious technique by which they explode grenades at various al-

titudes. The grenades are ejected from a flying rocket, exploded, and the time of the explosion and the position of the explosion very carefully measured by means of cameras on the ground. If you have one grenade exploded here and another here [indicating], the difference in time of arrival of the soundwave at the ground is simply due to this amount of path. Of course, the difference in time of arrival gives you the speed with which the sound then traveled from here to here.

It is well known that the speed of sound is a direct function of the temperature. It varies with the square root of the temperature. So from an observation like this, one can get the temperature in the upper atmosphere.

However, there is a catch, because there are winds in the upper atmosphere, and the winds add to the speeds that you measure. So one has to sift out the winds if one wants to get the temperature. But in sifting out the winds one gets the winds, too, and this is an important thing to know.

Mr. YATES. How do you get the winds?

Dr. NEWELL. By the effect of changing the angle of arrival and the time of arrival of the sound from what it would have been if there were no winds. In other words, in correcting the data to get temperatures, you get the effect of the winds and this gives you the winds.

We found in the Fort Churchill latitudes extremely high winds, winds of speeds up to as much as several hundred miles per hour. Of course, these are winds in a region where there is not much material. Nevertheless, here is an indication of the dynamic situation in the upper atmosphere.

We found also that the winds blow from the west in the winter—two W's is how you can remember it—and from the east in the summer. So there is a seasonal effect on the directions of these winds.

These will add to the sum total of data that one will use in learning about the mechanics and the dynamics of the upper atmosphere.

DAILY AND SEASONAL CHANGES

Mr. YATES. Is this a daily occurrence within those seasons? When you say the winds blow from the east in the summer, is this constant?

Dr. NEWELL. There is a diurnal variation, but the analysis of the data is not sufficient to bring it out yet. The winds blow from the east generally throughout the summer season, and from the west generally throughout the winter season.

Mr. THOMAS. At what altitude is that?

MOLECULAR VARIATIONS

Dr. NEWELL. We are talking about the region below 100 kilometers and above 30 kilometers, from 30 to 100 kilometers.

There is another interesting effect which we found at Fort Churchill which we did not find at White Sands in the Temperate latitudes. At White Sands a mass spectrometer was flown a number of times. A mass spectrometer is a device for separating out the different molecular and atomic species. It is an interesting gadget. By radio techniques it admits at a given time one mass but excludes all the others. By varying the voltage on this mass spectrometer, one can vary the molecular species which gets through to a collector where

these species are counted. The IGY mass spectrometer was so arranged that one could observe molecular species from below nitrogen to above nitrogen dioxide, that is, from mass numbers below 14 to mass numbers above 46. This covers fairly well the atmospheric gases, but unfortunately it does exclude helium, which is an important gas to look for.

With this mass spectrometer flown at White Sands, one looked to see whether or not the upper atmosphere was quiet. An atmosphere can be quiet even if there are winds. If these winds are all horizontal, they do not cause any mixing, as a turbulence would cause a mixing. If the atmosphere is quiet, then heavier molecules like argon will settle toward the bottom and the lighter molecules, like helium, will rise to the top.

We looked for this separation of argon and neon relative to nitrogen, and at White Sands we found that it did not occur. There were a few instances in the case of flights by the University of Michigan in which a small separation was detected, but it was very slight.

The general conclusion was that up to 130 to 140 kilometers, at least, the atmosphere was just thoroughly mixed, and that therefore the atmosphere was the same as at sea level in composition except for effects that might be produced by sunlight in charging the atoms or in dissociating, say, oxygen from the molecular form into atomic.

When we went to Fort Churchill, we thought we would find the same thing, but we felt that we had to check it to be sure. But we didn't find the same thing. We found that the separation did actually occur and that argon settled out, neon not quite so much.

We found this pronounced separation starting at 105 or 110 kilometers and continuing on upward to higher levels. This is extremely interesting, because it means that these winds then are essentially horizontal winds, and it is not a matter of mixing and turbulence such as we have in the troposphere.

Of course, this just generates more and more problems. We have to continue these studies to find out what happens in between these latitudes and find out how far upward this continues. Furthermore, we must fly a spectrometer that will look at helium for us, which is mass No. 4.

We shall try to do this toward the end of IGY. It was not originally in the IGY program, but having found this new bit of information, we are inserting it into one or two of the IGY rockets and will be able to get it in toward the end of the program.

This, then, is a description of the Fort Churchill program and some of the key things which have come out of it. I have not given you by any means all of the data which have come out of the Fort Churchill studies, but they are covered in my prepared statement.

ROCKET FIRINGS AT FORT CHURCHILL

I should like to point out that in the Fort Churchill program from July 4, 1957 to the end of March 1958, we fired 41 rockets and only 5 failed to obtain the data sought. Between January 25 and February 24, there was a string of 16 firings, all of them excellent. One right after the other worked.

To emphasize the state of the art, in this period 5 rockets were fired in a single 48-hour period to make associated and correlated observa-

tions. So this is what happens after you gain experience with these things, even though they are complicated. In fact, when we look at things like our satellite program and we see the failures which occur, we tend to be discouraged. We should remember that in something like the VANGUARD program we are only starting with a fairly complicated gadget.

Mr. YATES. You should have started a long time ago?

Dr. NEWELL. That is really the answer. However, we should not get discouraged because in the beginning of a program like this, some of these things do not work.

ROCKETRY DEVELOPMENT

The Aerobee-Hi which, as you know, showed such a good record, had five explosions in the beginning of its program when it was being developed for use. This is not considered unusual. This is the sort of thing that you have to go through with in order to learn what has to be learned. For example, one of these explosions ocurred during our check-out of the Fort Churchill operation and occurred because of something we had not expected. The nitric acid in the propellent tank was attacking the high pressure aerosphere that we use for blowing the propellant into the burning chamber, and caused it to corrode. This corrosion did not occur when the sphere was not under pressure, but it did occur when it was under pressure.

There was considerable benefit derived from having this explosion occur in our Aerobee because it turns out that the same material is being used in the Vanguard rocket and the same propellant is being used, and our having this explosion, when we had it, enabled the Vanguard people to solve that problem before they got on the launching pad with a much more expensive vehicle.

SOLID ROCKET FUELS

Mr. YATES. Did you come to any other conclusions as to whether solid fuel was better than liquid fuel in connection with these flights?

Dr. NEWELL. In the upper-air program, it is our conclusion that solid fuels will be better. I have a note here to discourse on that relative to the Soviet rockets a little later.

Mr. YATES. All right.

ROCKOON STUDIES

Dr. NEWELL. There are two other main programs in the IGY effort. One is that of using the Rockoon to study the aurora, the earth's magnetic field and cosmic rays.

With the Rockoon, Dr. Van Allen of the University of Iowa has been studying these three parameters; namely, aurora, cosmic rays and the earth's magnetic field from shipboard in the Arctic and in the mid-Pacific and in the Antarctic. He has collected quite a bit of data on the cosmic rays and has shown that during this period of maximum sunspot activity the cosmic radiation is only two-thirds of what it was during the last minimum. Contrary to what you might have suspected, to what you might offhand have thought, that the cosmic radiation would intensify, it does not.

Dr. Simpson pointed out yesterday that could be due to increased magnetic activity preventing cosmic radiation, which may still exist, from getting into the earth. In the case of the auroral studies, Dr. Van Allen was looking for the auroral particles Dr. Oliver mentioned earlier; but just prior to the IGY found that these auroral observations gave him X-rays in the auroral zones, not electrons and protons. His conclusion then was that the X-radiation was an emission from the original auroral particles.

During the IGY a number of soundings resulted in his finding of these X-rays. One might point out that this is only somewhat similar to the sort of thing he has found in these fast electrons creating X-rays in the satellite and in his counter which he then counts. Perhaps there is a tie-in between this X-radiation that he finds in auroral displays and the electrons and protons that he finds trapped in the magnetic field of the earth. This is another problem, a new area of investigation that has to go on to tie together these two or separate them, whichever it may turn out to be.

FUTURE DEVELOPMENTS

Mr. THOMAS. Is it not obvious, gentlemen, that you will be with us for about 10 or 15 years? Dr. Newell says that every time you make a discovery it entails nine others that he has to work on.

SOLAR RADIATION RESULTS

Dr. NEWELL. In the third area of our IGY research, the Nike-Deacon combination was used to study radiation from the sun. It is known that the sun emits radiation in the ultra-violet and X-ray wavelengths. We have been measuring that for some time and it was felt important in the IGY program to observe the subject in the ultraviolet wavelengths and X-rays during periods of increased activity. For example, during solar flares.

Therefore, a group at NRL instrumented a number of Nike-Deacons to measure any enhancement in radiation, any enhancement in the particular ultraviolet light that comes from hydrogen in the sun during the solar flare. This group set up its base of operations at San Nicolas Island off the coast of California, established contact with Sacramento Peak in New Mexico and with the Climax Observatories, and arranged then to fire their rocket at a word from either of these observatories, telling them that a solar flare had started. The idea was to catch the total progress of any increase in X-rays or ultraviolet light. The group found during solar flares that there was a marked increase in X-rays. They found that the X-rays were associated with a marked increase in the D region of the ionosphere. This is the region that I indicated was associated with the polar blackout up at Fort Churchill. In fact, it appears that the enhanced X-radiation may cause the increase in the D region of the ionosphere that is associated with radio blackouts. The more we can learn about these, the further we will progress in improving radio communications.

The group did not find any enhancement of the hydrogen radiation, Lyman-alpha radiation. This may have been due to the fact that the ultraviolet radiation occurred much more quickly and was over before

they could get the rocket up into the upper atmosphere. It takes a minute from the time they get their notice from Sacramento Peak or from Climax to get the rocket up into the upper atmosphere. This minute is pretty good going when you realize that this involves firing a rocket up to those altitudes. All the operation of firing that rocket has to be gone through. However, the rocket is on the launching stand and ready to go.

This sort of experiment was the basis for the solar radiation experiment in IGY satellites, the ones that Dr. Porter described to you yesterday. In fact, it is on the basis of these observations that one shifted from the ultraviolet radiation study which had been scheduled for the first IGY satellite to an X-ray study. We are presently considering the question of whether the next one should not even be an X-ray satellite. Here is a sample of how satellites and sounding rockets tie in together.

ROCKETS VERSUS SATELLITES

At this point I would like to point out that the one does not do the other out of a job. In general you use the satellite for making observations over a long period of time at levels above the atmosphere. You use the sounding rocket for making vertical snapshots of the atmosphere within the atmosphere at essentially a given instant of time. The two can carry on this research hand in glove, so to speak.

INTERNATIONAL IGY ROCKET PROGRAM

As to my final comments, I thought I would like to direct you for a moment toward our place in the total IGY program relative to other countries. The only other rocket-sounding program that we know of that has anything comparable to ours is the Soviet one. They have hundreds of rockets, too, in their program. However, France is firing rockets comparable to our Aerobee. The United Kingdom has a solid-propellent rocket that is comparable in size to our Aerobee, but it has the advantage of being a solid-propellent rocket. There is an advantage here. When you are dealing with a liquid-propellent rocket you have the trouble of handling sometimes nasty propellents.

ROCKET FUELS

For example, the Aerobee uses red, fuming nitric acid and aniline, neither of which is pleasant. Once you load the rocket and once you pressurize the rocket for firing, the vehicle is under pressure. This is a dangerous thing. It is like a loaded bomb sitting in your launching tower. If your operation calls for waiting for some geophysical event, like the aurorae, then you have your problems. It was exactly this that led to the explosion of the Aerobee, about which I spoke earlier. We were waiting for an aurora and the rocket was pressurized and all of a sudden let loose. With a solid-propellent rocket, you can put it in the tower and just wait and wait as long as you want and fire it when you want. This was done with the Nike-Deacons and the solar flare program, of which I spoke a moment ago.

The United Kingdom has the solid propellent rocket and Australia has been doing something with balloon-launched rockets. As far as

I know, they have not launched any official IGY firings. The Japanese have a solid propellent rocket program. It is a small program and I do not yet have any information from them as to any results they may have obtained. They also have a rockoon program. The Soviets, France, the United Kingdom, Australia, and the Japanese, together with the United States, comprise the total IGY rocket program.

Mr. YATES. Are the British rockets projected by solid fuels going as high as American rockets using liquid fuels?

Dr. NEWELL. No, sir.

Mr. THOMAS. I believe you said 30 miles a while ago for the British?

Dr. NEWELL. No. Their rockets will go to 150 kilometers.

Dr. TUVE. What payload?

Dr. NEWELL. About 150 pounds. The same sort as ours.

I thought I would close by making a comment on the Soviet rocket program.

SOVIET ROCKET PROGRAM

You undoubtedly have read of the Soviet geophysical rocket, one of which was launched on the 21st of February of this year and carried a ton and a half of equipment to 473 kilometers, which is 293 miles. The question immediately arises as to why cannot we use big rockets like this and do big things like that?

The answer here in this case is that we do not want to. Our use of smaller——

Mr. THOMAS. Could we, if we wanted to right now and given the state of the art?

Dr. NEWELL. We might, if we used Thors.

Mr. THOMAS. The Thor is a large enough rocket? Does it have the thrust?

Dr. NEWELL. Yes.

Mr. YATES. Is this attributable to fuel, or what?

Dr. NEWELL. I would not know. What we do not want to do is to use a big rocket like this for upper air soundings. We consciously decided 8 years ago to use smaller vehicles.

VALUE OF SMALL-ROCKET SYSTEMS

Mr. THOMAS. Why did you make that decision?

Dr. NEWELL. For several reasons. If you use a large rocket of this sort, you are putting all your eggs in one basket.

Mr. THOMAS. Perhaps we might go off the record a moment.

(Discussion off the record.)

Dr. NEWELL. We do not want to do this because then you are putting all your eggs in one basket. When you make a number of experimental observations, all at once the way they did, that is what you do. In fact, it is interesting to note that the experiment of equipment carried in that geophysical firing was apparently identical to what they launched in their Sputnik No. 3.

Mr. THOMAS. Will you tolerate another interruption?

We are about to change our minds. Why should not this information about the Thor be on the record?

Dr. NEWELL. I see no reason why it should not.

I might make this statement: With our presently available techniques and vehicles we, too, could put up a ton to a ton-and-a-half payload instrumentation, if we wished to do that; that is, in a vertical sounding trajectory. I emphasize that.

If you perform 9 or 10 different experiments in a given rocket, then you find that one of them will be compromised by the others. They will all have their special demands. For example, if you are making a measurement of the pressures and the densities at those high altitudes, you usually want the rocket to roll and spin. This causes a modulation on your gage, which modulation you use for calculating the density. At the same time if you are carrying on an ionosphere experiment, you want the rocket to be stable and not spin. One or the other is going to be compromised.

Mr. YATES. What are the Russians doing then?

Dr. NEWELL. This is a good question.

Mr. YATES. They know that, too, do they not?

Dr. NEWELL. I assume they do. Now I am only guessing but they may have——

Mr. YATES. Presumably they know that they can get a better result for the first type of program by a rocket that rolls and spins. Then, by the second type of experiment, they may use a rocket that is stable. Why should they combine them?

Dr. NEWELL. I was giving you a typical example.

Mr. YATES. I wondered if they knew this and why they would still resort to it inasmuch as you presumably get no value for either experiment by a rocket that does both.

Dr. NEWELL. You are in danger of compromising some of the experiments at least.

Mr. YATES. Have you seen the results of these experiments?

Dr. NEWELL. No.

Mr. YATES. This has not yet been made available?

Dr. NEWELL. No. I cannot answer your question as to what reasoning they went through. I simply go through the reasoning as to why we prefer to use the smaller rockets of equivalent altitude performance.

Mr. YATES. Can we assume that they are also shooting rockets for single experiments as we are?

Dr. NEWELL. We do not know.

Mr. BOLAND. Can you get the same information from the small rockets? You fire more rockets and then get more definite information; is that right?

Dr. NEWELL. Yes. That was the next point I wanted to make. For the cost of one of the big rockets, you can then take a single experiment and fly it many times at many different times of day, many different seasons, or you can take all of the individual experiments and fly them separately in just the way they should be flown, at just the time they should be flown.

ROCKET DEVELOPMENT

Mr. YATES. Is it possible because of the size of the rockets that the Russians shot up, that there was contained in the rocket mechanisms that would spin in part of the experiment and then keep stable for another part?

Dr. NEWELL. It is possible. However, I am inclined to think—this is only a personal guess now—that this February 21 firing they publicized was a rehearsal for Sputnik No. 3 because of the fact the instrumentation is so similar and the payload weights equivalent, and so on.

Mr. THOMAS. There was some showmanship in it, too, and propaganda?

Dr. NEWELL. Yes. Then, again, we also reasoned that if you put all of these experiments into 1 rocket, the failure of that 1 rocket represents a total failure.

Mr. THOMAS. There is no question then in your mind that we could have done just exactly what the Russians have done, had we wanted to do it?

Dr. NEWELL. There is no question whatever.

Mr. YATES. How much does the Russian vehicle weigh?

Dr. NEWELL. They say a ton and a half for the payload.

Mr. YATES. I was under the impression—this again is in orbit—we could not put more than a thousand pounds into orbit; could we?

Dr. NEWELL. At the present time, no.

The Vanguard put 50 pounds in orbit and the Explorer, 30 pounds in orbit.

Mr. YATES. Why the difference? Is it the difference in engines, or fuels, or are they using nuclear energy? What have we found out that the Russians have that we do not have? Have we found anything out on this at all?

Dr. NEWELL. You are asking me to speculate on the difference between what they did and——

Mr. YATES. No; I was wondering if anybody knew why they were able to do this and we were not. Is it because they know more about fuels, whether they have a better engine, or what not, that is what I wanted to know.

Dr. NEWELL. I think personally—and this should go in as my personal opinion——

Mr. THOMAS. Go ahead and speculate.

Dr. NEWELL. It is simply a matter of their deciding to do it. If we had an appropriate lead time and decided to do this, we could have done it.

Mr. YATES. What do you mean by "appropriate lead time"?

Dr. NEWELL. A number of years back. Let me point out that there are two approaches to launching an artificial satellite, if you want to look at this question. One way is to do it by the hammer and tongs method. Take a vehicle and with this tremendous vehicle, give your object a nice big boost and then it is in orbit.

Mr. THOMAS. You have answered Mr. Yates' question.

What we are lacking now is that thrust power?

Dr. NEWELL. What I wanted to do was to give you the background before I stated our position.

ROCKET THRUST

Mr. YATES. What gives it the thrust?

Dr. NEWELL. Your tremendous vehicle can be built. We could build it and we could have built it if we had gone into the matter of building a large vehicle. This is really the easy way of putting a

satellite in orbit. With a tremendous vehicle you do not have to worry about doing every little piece of your operation exactly right. There is another way of going about it. That is to take a highly refined, carefully designed vehicle that just does the job. This is the Vanguard vehicle. The Vanguard vehicle, now that it is working, is a real advance in the state of the art. It is an advance in the use of propellants to their maximum efficiency. It is an advance in the use of structures to their maximum efficiency, but it is the hard way to do the job. Once it is done, you have contributed a lot to the state of the missile and rocketry art. Not that people will use Vanguard for a missile, but they will use the techniques learned in their new missiles.

Mr. YATES. I will agree with what you have said and yet the question still prevails in my mind that using the other method the Russians have gained some knowledge that we have not gained. We have gained in the machining, mechanization of the instrumentation, but yet at the same time they have accumulated certain knowledge as a result of having shot this thing into orbit that we do not have. Is that not true?

Dr. NEWELL. There is no doubt about that.

SOVIET AND UNITED STATES EXPERIMENTS

Mr. YATES. Dr. Porter testified yesterday that this was a very capable and very excellent flying laboratory in Sputnik III, and they had instrumentation that we were not contemplating for our use in a satellite before 1960?

Dr. NEWELL. You are going over into instrumentation there. In the case of the launching of such a big vehicle, and having it available, unquestionably they have learned a lot about that sort of thing. What I am pointing out is that we are following a different pattern and have also learned a lot, and maybe more than they have learned with their big vehicle. I am saying that if we had started a number of years ago, we could have come up with a big vehicle, too. We just did not.

Mr. THOMAS. Do you need that big vehicle that the Russians used to put their satellite in orbit in the firing of an ICBM?

Dr. NEWELL. There is the gain, of course; with a big vehicle you can do both. In the Vanguard vehicle, you really do not have an ICBM. You do not have the payload capacity.

Mr. THOMAS. Answer this question.

Dr. NEWELL. Yes.

Mr. THOMAS. They may have a little edge on us. Give it to them.

Dr. NEWELL. I say that we are behind in what we are doing in the sense that we did not decide to do certain things and they did. Therefore, they have gained a lap on us.

Mr. THOMAS. That is a good, honest statement.

Mr. YATES. What are we doing now? That is not part of this discussion.

Mr. THOMAS. Are we detracting from your statement?

Dr. NEWELL. No; I concluded my statement.

EVALUATION OF PROGRAMS

Mr. BOLAND. I am satisfied from what he has said so far about the rocket program. We have learned just about as much about what we want to learn as they have learned from their larger vehicles.

Mr. THOMAS. Maybe better.

Dr. NEWELL. Perhaps better. Time will tell. We do not know. We will have to wait.

DATA EXCHANGE

Mr. YATES. Based upon what Dr. Porter testified to; namely, while it is true all of this information will be made available to all of the countries participating in the IGY, I ask when will it be made available?

The second point is, How much will be made available of bare essentials and minimum and maximum amounts? When they shoot up a rocket which contains instruments, such as we were not contemplating using during the IGY, I think perhaps we cannot say that our rocket program is as good as theirs is.

I see the doctor itching to reply and I want to hear what he has to say.

Dr. NEWELL. Dr. Porter said we were not contemplating using those instruments in the satellites during the IGY, but are using them in our vertical sounding rockets. We are using the mass spectrometer.

Mr. YATES. Do you gain certain information in satellites you do not gain in your ordinary rocket firing?

Dr. NEWELL. True.

Mr. YATES. This is probably what he had in mind.

Dr. NEWELL. I am sure.

Mr. YATES. I did not know Mr. Boland meant to limit his comments to the rocket program.

Dr. NEWELL. If you include the two, then we are definitely behind. If you just separate them out and talk about the verticle sounding program——

Mr. BOLAND. Just as Mr. Yates indicated, I am talking about the rocket program outside of the satellite program.

Mr. THOMAS. There is one thing we can all agree on. As long as we have such distinguished gentlemen as Dr. Newell and the rest of these gentlemen here, we are in pretty good hands.

We want to get Dr. Tuve to clarify a little situation that arose a while ago. What about your DEW line? How effective is it now?

Maybe this ought to be off the record. We will leave the question on the record and take the answer off the record.

(Discussion off the record.)

CONTRIBUTIONS TO THE IGY

Mr. YATES. I have a question to ask in terms of contributions which each of the nations will make.

Are we in a position to appraise what the various nations of the world are contributing to the program as of now, or is it too early in the program to know the contribution that the various nations are making?

Have papers come out and have you had meetings to appraise what each of the nations is doing?

Certainly at the conclusion of the program you will know what the scientific progress has been?

WORLDWIDE COOPERATION

Dr. KAPLAN. I would say that in Dr. Revelle's testimony, he did mention the remarkable cooperation and future planning in oceanography and this probably is a good general example.

I mentioned earlier in my own testimony that Mr. Odishaw who now directs the IGY World Data Center, perhaps may want to say a word on the flow of information.

Mr. ODISHAW. I would simply say that the data flow is satisfactory. It is not at as high a level as we had originally planned, but problems involved in this complex transmission from field stations have been a factor, and not a lack of cooperation. Cooperation is there, and the report that Dr. Kaplan asked me to prepare summarizes the flow of the data and what countries it comes from. It is a very, very good and an encouraging picture.

Mr. THOMAS. Gentlemen, we certainly are grateful to you for coming back the second day and these last three statements have certainly been wonderful. We are indebted to all of you.

The country and the world is greatly indebted to you. As far as I am concerned, I am not too disturbed as long as we have men like you gentlemen here taking the lead in this program. We are not going to be behind anybody in the world. If we should momentarily fall behind in this little narrow field or that narrow field, it will not be long before we lead in that field.

Dr. TUVE. The flexibility of the mechanism setup in the National Science Foundation is one of the real accomplishments. We get an intelligent hearing when we face changed situations. This is what I tried to say yesterday. I think that the existence of your committee and the National Science Foundation provided an understanding of our problems because we are talking to people who understand.

Mr. THOMAS. We cannot put blind bridles or collars on these scientists. It is an art that has got to have flexibility. They have got to move as they get ready, and when they get ready and in the direction they need to move.

Dr. KAPLAN. I want to second Dr. Tuve's statement about the cooperation of the Foundation. That has been a new area of cooperation and it has worked out very well.

Mr. THOMAS. I think you gentlemen in the International Geophysical Year have set a pattern of worldwide cooperation that nations and governments, and particularly our good State Department, can take a leaf out of your book. I sincerely mean that. Thank you, gentlemen, and good luck to all of you.

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